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Vol. 182 JULY, 1916 No. 1

THE LOSSES IN CABLES AT HIGH FREQUENCIES.*

BY

EDWIN F. NORTHRUP, Ph.D.,
Member of the Institute,

AND

R. G. THOMPSON.

When current passes through solid metal conductors at the high frequencies employed in wireless telegraphy and telephony the heat-losses are needlessly excessive, and, to diminish these, various types of stranded cable are employed. The object of this investigation is to *experimentally* determine if there is any appreciable difference in the losses in cables which depends upon the arrangement, the size, and the insulation of the individual strands which make up a cable, and to determine what combinations of these various features will give a cable best suited for use at high frequencies under specified conditions.

The high-frequency resistance of a given length of cable depends upon many variables, among which are the following:

The specific resistance of the wire.

The shape of the cross-section of the cable.

* Communicated by E. F. Northrup. The material of this investigation was obtained by R. G. Thompson and C. G. Monteiro for their theses leading to the degree of E. E. from Princeton University. The methods and planning of the research are due to E. F. Northrup. The presentation here given was prepared jointly by E. F. Northrup and R. G. Thompson.

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The dimensions of the cross-section of the cable.

The number of strands per unit cross-section of the cable.

The ratio of the cross-section of the copper in the cross-section of the cable to the total cross-section of the cable.

The type of stranding or braiding.

The type of winding in respect to twisting of the strands.

The type of winding in respect to inductive or non-inductive winding.

Owing to the variety and the complexity of the arrangements of strands employed in cables and the many variables which determine the resistance of cables to the passage of high-frequency currents, mathematical calculation of the power-loss or the resistance for any particular cable at a given high frequency is practically impossible. It is possible, however, to experimentally investigate these quantities for selected types of cables which may be taken as typical of those which are used in the construction of high-frequency apparatus. The authors are not aware of the existence of any exact experimental data on the losses of different kinds of cables at high frequencies which might aid in the selection of the best type of cable for a particular purpose.

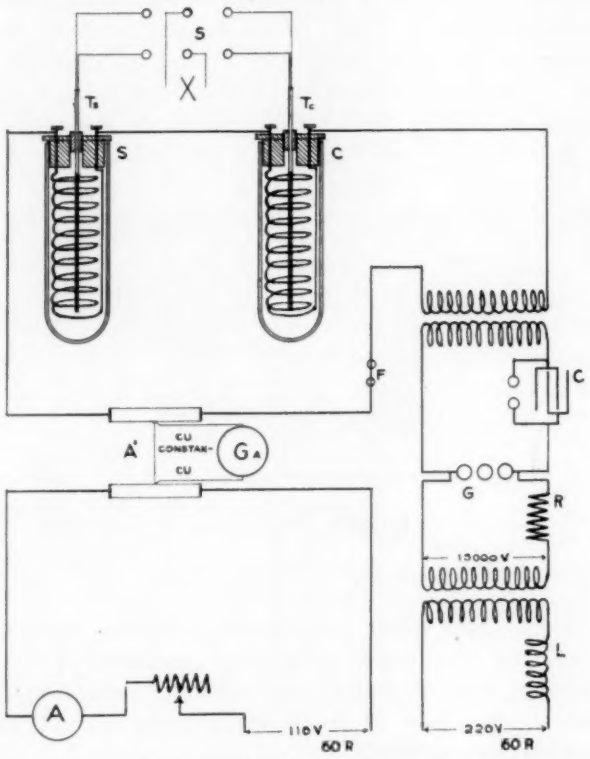
Stranded cables are much used for the secondary windings of the high-tension transformers employed in radio work, and this fact gives any reliable experimental data commercial value. In what follows we have attempted to supply such data by giving the results of a series of tests conducted with *great care* on several types of copper-wire cable. We have investigated for each of these cables both the *actual* and the *relative* losses for known high frequencies and known effective currents. We have, however, recorded only relative losses in the table of results. Where relative losses are considered, solid round-copper wire has been selected as a standard for making the comparisons. Sufficient data are given, however, so that the absolute losses in the cables of particular sizes and types tested can be calculated without reference to a solid-wire standard.

DESCRIPTION OF TESTS.

At the frequencies employed it may be safely assumed that all the losses in a conductor carrying an electric current are manifested as heat; hence, in comparing the different types of cable, a method was adopted whereby the relative and the absolute heat-

losses of different samples of cables could be measured. Equal lengths of solid wire and cable having very approximately the same cross-section were wound in coils and immersed in kerosene in Dewar bulbs, as shown in Fig. 1. These bulbs held each about 1.2 litres. The high-frequency current was obtained by means of a

FIG. 1.



Connections for high-frequency test.

circuit, arranged as shown in Fig. 1, which is an ordinary inductively coupled sending-station circuit as used in wireless telegraphy.[1] *

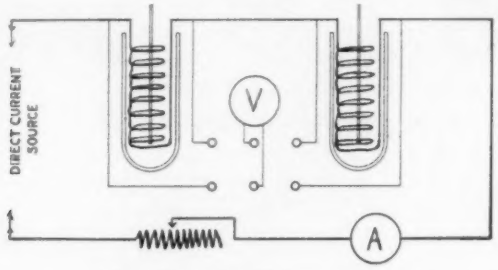
An inductive coupling was used in order that all the current in the secondary would be high-frequency. This current was measured by comparing it with measured low-frequency current, the

[1] * Reference numbers refer to the bibliography at end of paper.

equality of the currents being made known by means of a thermocouple (Fig. 1, A'), and the temperatures of the bulbs were measured with resistance thermometers, T_s and T_c.

After the coils had been sealed in the bulbs they were allowed to stand for at least two hours in order that the whole contents might come to room temperature. The high-frequency current was then passed through the coils, in some cases wound inductively and in others non-inductively, joined in series, the time of run being 22 minutes for the non-inductive coils and 45 minutes for the inductive. The inductance added to the circuit, when coils wound in the form of helices were tested, decreased the value of the current; hence in this case the time of run had to be made longer to get a satisfactory temperature rise. Readings were taken of time, current, and temperature rise for each bulb. The current

FIG. 2.



Connections for direct-current test.

readings were taken every two minutes, and the average of all these values for the run was used in the computation. After the high-frequency test, the bulbs were allowed to stand undisturbed until they again came to room temperature, which generally required about twelve hours.

Connections were next made as shown in Fig. 2 and a direct-current test made, the time of run being the same as in the high-frequency test. The value of the direct current was kept constant throughout the run, and so chosen that the temperature rise in the bulb containing the solid-wire coil was about the same as that obtained in the high-frequency test. Readings were taken of time, current, temperature, and voltage drop across each coil. Readings of voltage drop across each coil were taken every five minutes, the average voltage during the run being used in the

computations. For every high-frequency test a direct-current test was made, as it was necessary to determine the constants of the bulbs every time the coils were changed.

From the direct-current test the watt input for a given time, and thereby the watt-minute input per degree rise in temperature, was obtained for each bulb. From these data the watt-minute input was calculated for each bulb for the high-frequency test. The ratio of the watt-minute input for the bulb containing the cable coil to the watt-minute input for the bulb containing the solid-wire coil is the true ratio of the losses in the two coils.

Two solid-wire coils wound with wire of the same length and resistance were used as standards in making all the tests. Two coils of each kind of cable wire were also wound. In testing a certain cable, four complete tests were made, using the four coils in different combinations. The procedure practically eliminates the possibility of error in the final results obtained due to any inherent defects, such as a short circuit, in the coils themselves; for it is not probable that the same defect would be found in each of two coils. Hence when the four tests checked with each other within 2 per cent. it was assumed that the result was correct. For each cable the loss was measured for both inductive and non-inductive windings.

After the direct-current test, the bulbs were again allowed to cool and a 60-cycle alternating-current test was made, using the same value of current as in the direct-current test. Readings were taken of the time, current, and temperature, and the computations were made in the same manner as in the high-frequency test.

In all the tests the length of wire in the different coils tested was the same; the same oil was used for all the tests, and the same amount of oil was used in each bulb, because at high frequencies the losses in different oils are not the same.

The specific direct-current resistance was assumed to be the same for all the samples tested.

The same standards of No. 12 solid wire were used when testing all the cables, and the cross-section of all the cables was approximately that of the standards with which they were compared.

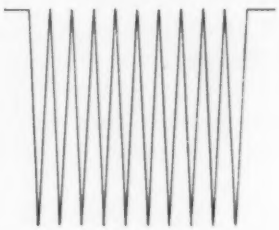
The conditions were the same for all the tests. All tests were started with the bulbs at room temperature to eliminate errors due to radiation. These errors would, however, be very small in any

case where a cable in one bulb is compared with a solid wire in a very similar bulb.

DESCRIPTION OF APPARATUS.

Coils.—The length of wire used in each coil was 64.5 feet, as this was the amount found to be most convenient for making coils of a size suitable for the Dewar bulb. The coil was formed by winding the wire around a paraffin-coated cylinder of brass, 2½ inches in diameter. The axial length of the coil was made 1 foot. The coil, after being wound, was removed from the metal winding-form before it was tested. The type of non-inductive winding used is shown in Fig. 3. Of all types of non-inductive winding which might have been used in the tests, this type has the least electrostatic capacity. The inductive coils were wound on the same cylinders

FIG. 3.



Winding for non-inductive coils, shown developed from a cylinder.

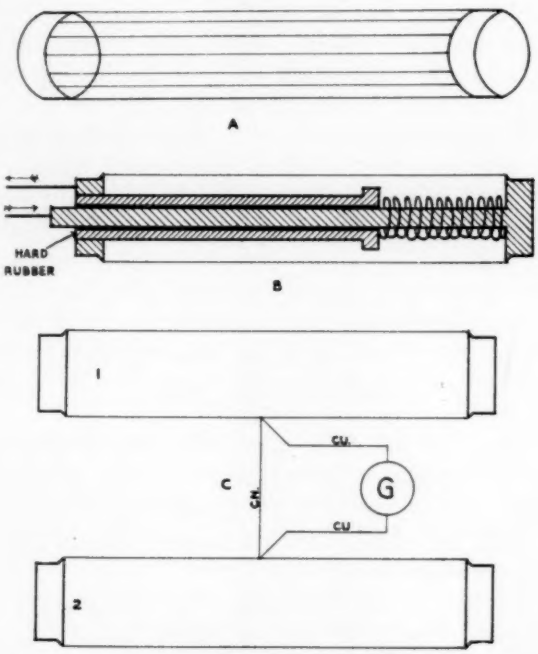
in the form of one-layer helices. After winding the coil on the cylinder, it was baked at 100° C. for a few hours, then soaked for three hours in an insulating varnish commercially used for impregnation, and baked again at 100° C. until dry. The coil was then soaked and baked again. The cable-coil was treated in this manner in order that the varnish might soak in and insulate one strand from another as much as possible. After baking the coils, the cylinder was removed and the terminals of the coil were soldered to the connections at the lower part of a wooden top which fitted into the Dewar bulb (Fig. 1). The wooden top was sealed to the bulb with hot paraffin. Particular care was taken in each test to see that the coil was totally immersed in the kerosene.

Dewar Bulbs.—The Dewar bulbs used for the tests were *unsilvered*. They were 15 inches long and 4 inches in diameter.

No difference in results could be obtained by interchanging the bulbs, and they were found to have the same cooling constants. The vacuum of the Dewar flask was very good, as was proved by the fact that no electrodeless discharge was observed in any of the tests.

Silvered Dewar bulbs cannot be used for tests of this character. It was found by trial that a silver coating makes a secondary cir-

FIG. 4.



High-frequency ammeter.

cuit in which currents are induced when a helix within the bulb carries high-frequency current. The heat developed in the silver coating was comparable with the heat developed in the coil itself.

HIGH-FREQUENCY AMMETER.[3]

The type of ammeter employed for measuring the high-frequency current will be understood by reference to Fig. 4. About twelve wires of manganin were disposed on the circumference of a

cylinder, running lengthwise of the cylinder and equally spaced from each other (Fig. 4, *A*). Low-frequency or high-frequency current will be conducted through a set of wires thus arranged in the same manner. These wires were attached at each end to brass disks. A spring arrangement (shown in *B*, Fig. 4) maintained them taut. Current was led in to one end of the wires along the axis of the cylinder. The combination as a whole was thus non-inductive. Two of these cylinders, made exactly alike in all respects, were constructed. One of these cylinders, which we shall call a spool, carried the high-frequency current and the other the comparison current. When the current through each of the spools has the same effective value the heating effect of the current of each spool is the same, not only for the spool as a whole but for each individual wire. By connecting together near the middle point one wire of each spool with a piece of very fine constantan wire, and also fastening at the points of junction fine copper wires, a thermocouple is made which, connected to a sensitive galvanometer, gives a very delicate indicator of the condition that the two spools are carrying currents of equal heating effects. As this type of high-frequency ammeter proved both convenient to use and accurate, and as it can be constructed for carrying currents of any magnitude, we give some further details of the construction of the one we employed.

The wires used for each spool were No. 38 manganin wire and twelve in number. The length of the wires, or the distance between brass-end pieces of a spool, was 3½ inches. Care was taken to solder the wires in such a manner that each one had the same length and resistance.

The procedure in measuring the high-frequency current consisted in passing this current through spool No. 1 (Fig. 4, *C*), and 60-cycle alternating current in series, through an ammeter, an adjustable rheostat, and spool No. 2, and varying this latter current until the galvanometer attached to the thermocouple gave no deflection. When this adjustment is made both junctions of the thermocouple are at the same temperature and, assuming the spools are identical and under like conditions in respect to loss of heat, the effective values of the high-frequency current and the low-frequency comparison current are the same. An accurate alternating-current ammeter permitted the reading of this latter current with precision. Sixty-cycle alternating current instead

of direct current was employed as a comparison current, for the reason that when direct current is used some of this direct current finds its way through the galvanometer with the best attachments of the thermocouple junctions to the wires which it is practical to make. This difficulty is avoided by the use of the alternating current.

While it is impossible to make two spools which are in all respects identical and which lose their heat at the same rate, the lack of symmetry was provided for and made to have no influence by shunting the spool of higher resistance until, on the passage of equal measured currents of low frequency through each spool, the galvanometer deflection was reduced to zero. In using the meter for measuring the high-frequency current the low-frequency current was passed through the shunted spool, because a low-frequency current will divide between the wires of the spool and the shunt according to Ohm's law, while high-frequency current will not so divide. To insure uniformity in its performance the meter was mounted in a tin box and immersed in paraffin oil. For all the experimental data obtained it was assumed that the error in measuring the effective value of the high-frequency current did not exceed 5 per cent.

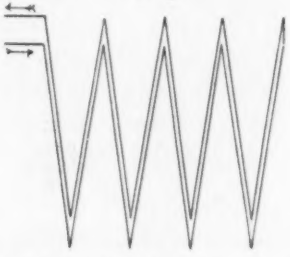
RESISTANCE THERMOMETERS.

It was found by using a mercury thermometer that the temperature in the bulbs, while the test was in progress, was not the same at different levels of the oil in the bulb. The maximum difference was about 0.5° C. It was further found that when the tests were made on inductively-wound coils at the high frequency used a current was induced in the mercury in the thermometer bulb. The magnitude of this current and its heating effect were such that readings taken with a mercury thermometer were worthless. To avoid this latter difficulty and also to be able to obtain at a single reading the average temperature of the oil from its bottom to its top layer, two carefully-constructed resistance thermometers were made as follows:

Copper wire was selected for the thermometers because over moderate ranges of temperature its resistance increases linearly with the temperature. Each thermometer was made of 385 feet of No. 36 B. & S. silk-covered wire. The type of winding was adopted which would make the thermometer strictly non-inductive,

as it must be when used in the presence of high-frequency current. The wire was doubled once on itself and then looped up in the form of a skein, the length of the skein being made about equal to the depth of the oil. The development of the winding is shown in Fig. 5. This wire skein was then "aged" by heating in a gas oven at 140° C. for twelve hours. A skein was then slipped into a thin-walled glass tube, 16½ inches long and ¼ inch outside diameter, and closed at the bottom. The completed thermometers were adjusted under identical temperature conditions until their resistances were like each other to within 0.01 of 1 per cent. The resistance of each thermometer was 159.43 ohms at 21.2° C. After the resistances had been adjusted the thermometers were completed by filling the tubes with paraffin.

FIG. 5



Winding for resistance thermometers.

The resistances of the thermometers were measured by means of a very accurate Leeds & Northrup Wheatstone bridge, a ratio of 1000 to 100 being used in the bridge. Connections were made with a mercury-contact switch (Fig. 1, *S*), and the resistance of the leads from the thermometers to the bridge was entirely negligible. The measuring current through the thermometers was reduced until its heating effect was entirely negligible. Readings of resistance were accurately determined, relatively to each other, to 0.01 ohm, and this determined changes in the temperature of each bulb to 0.01° C. The temperatures were taken from a previously-drawn curve giving the straight-line relation between resistance and temperature.

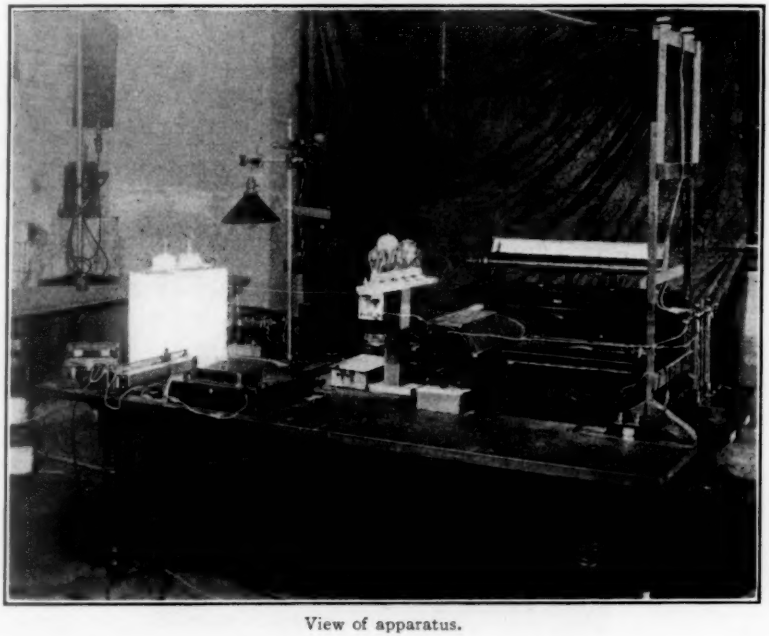
As the skeins forming the thermometers equalled in length the coils tested, and were only a little less in length than the depth of the oil in the bulb, a single temperature reading gives the mean temperature on the interior of the bulb. The coils tested and the

length of the thermometer skeins was about 12 inches. The carefully-made non-inductive winding employed in the thermometers prevented any development of heat in the thermometers from induced currents at the highest frequencies used.

WAVE-METER.[4]

All determinations of frequency were made with a wave-meter which was kindly loaned for this investigation by the American Transformer Company.

FIG. 6.



View of apparatus.

THE OSCILLATION CIRCUITS.

Certain devices were employed to obtain continuous and uniform sparking at the double spark-gap G (Fig. 1). A resistance R of 40,000 ohms was inserted in the high-tension side of the transformer. This has the effect of limiting the condenser charging current so that *one and only one* spark passes at the gap G for each half-cycle of the primary current. The regularity of the discharges at the gap G was further improved by the insertion

of a large inductance L in the primary circuit of the transformer and also by blowing a jet of air on each gap of the double spark-gap.

Incidentally, the above adjustments can be used effectively for obtaining uniformly-timed very brilliant discharges for instantaneous photography of the most rapidly moving objects.

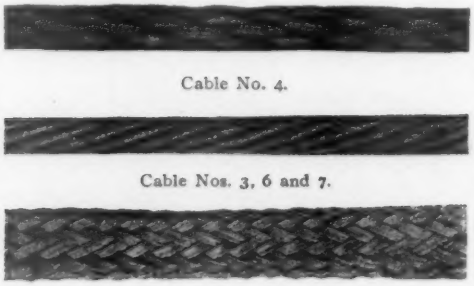
(For an application of this method to photography see "An Experimental Study of Vortex Motions in Liquids," by E. F. Northrup, JOURNAL OF THE FRANKLIN INSTITUTE, September and October, 1911.)

Description of Cable Tested.

No.	Type	Size of wires	Number of wires	Cross-section, c.m.	Diameter, t.c.c.	Equivalent B.S.	Pounds per 1000 feet
1.	Parallel	30	65	6533	0.103	12	19.50
2.	Twisted	30	65	6533	0.125	12	21.50
3.	Stranded	36	238	5950	0.116	12–13	18.88
4.	Hawser lay	36	231	5775	0.118	12–13	17.87
5.	Braided	36	240	6000	[0.097 x 0.177]	12–13	19.63
6.	Enamelled	36	259	6475	0.108	12	20.72
7.	High-frequency	28	24	3840	0.108	14	11 52
	Solid	12	1	6530	0.103	12	19 77
	Solid	14	1	4107	0.082	14	12.44

Illustrations of some of the cables are given in Fig. 7.

FIG. 7.



Cable No. 4.

Cable Nos. 3, 6 and 7.

Cable No. 5.

Types of cables tested.

Cable No. 1.—In this cable all the strands are parallel.

Cable No. 2.—This cable was made from Cable No. 1 by twisting a length of 70 feet about 1200 times, which shortened this length to 64.5 feet.

Cable No. 3.—Thirty-four No. 36 wires are twisted together. Seven of these strands are then cabled around each other in the ordinary rope-weave.

Cable No. 4.—Eleven No. 36 wires are twisted together in small strands. Three of these small strands are then cabled around each other. Seven of these larger strands are then cabled around each other, which gives a hawser rope-weave.

Cable No. 5.—This cable is made by braiding together twenty-four strands, each strand consisting of ten No. 36 wires. The cross-section is rectangular.

Cable No. 6.—Thirty-seven No. 36 enamelled wires are twisted together. Seven of these strands are then cabled around each other in the ordinary rope-weave.

Cable No. 7.—Four strands of No. 28 enamelled wire are twisted together and covered with a wrap of Tussah floss. Six of these strands are then cabled around a core of hemp.

Cables No. 6 and No. 7 are insulated with a silk covering; all the rest of the cables are insulated with a (t.c.c.) triple-cotton covering.

With the exception of Cable No. 5, the cross-section of all the cables was circular.

The enamel insulation on Cables No. 6 and No. 7 is said to stand a breakdown test of from 400 to 600 volts alternating. All the rest of the cables were made of bare wire and treated with an insulating varnish.

RESULTS OBTAINED IN THE MEASUREMENTS.

Results obtained in our measurements are given below in tabulated form. The precise meaning and the significance of the different numerical quantities given in the table of results will be clearly understood from the following definitions of the symbols we have employed and the simple relations between these symbols, used to express the meaning of the tabulated quantities:

Symbols: High-frequency Test:

t = time in minutes, = total time of a single test.
$(I)^2$ = square of high-frequency current in ampères.
T' = rise of temperature of bulb in degrees C.

Direct-current Test:

t = total time of test in minutes.
I = current in ampères.
$E = IR$ = mean voltage drop during test at terminals of coil.
T = rise in temperature of bulb in degrees C.

In both the high-frequency and direct-current tests the temperature at the time of starting the tests was room temperature, and the rise of temperature, T' or T, is the degrees rise above room temperature.

Relations Employed in Expressing Results: Direct-current Test:

W = total watt-minute input = EIt.
w = watt-minute input per degree rise = W/T.
R = ohmic resistance of coil = E/I.

High-frequency Test:

W' = total watt-minute input = $wT' = (I')^2R't$.
R' = high-frequency resistance of coil = $W'/(I')^2t$.

1. Ratio of high-frequency resistance of cable to high-frequency resistance of standard = R'_c/R'_s.

(The subscript c is used in each case when the quantity refers to a cable coil, and the subscript s when it refers to a solid-wire coil.)

$$\frac{R'_c}{R'_s} = \frac{(I')^2R'_ct}{(I')^2R'_st} = \frac{w_c\,T'_c}{w_s\,T'_s} = \frac{W'_c}{W'_s}.$$

2. Ratio of high-frequency resistance to direct-current resistance of a coil = R'/R.

$$\frac{R'_c}{R_c} = \frac{(I')^2R'_ct}{I^2R_ct} = \frac{W'_c}{W_c}.$$

3. Expressions for the ratio, $\dfrac{R'_c/R_c}{R'_s/R_s}$.

$$\frac{R'_c/R_c}{R'_s/R_s} = \frac{R'_c}{R'_s} \times \frac{R_s}{R_c} = \frac{(I')^2R'_ct}{(I')^2R'_st} \times \frac{I^2R_st}{I^2R_ct} = \frac{w_cT'_c}{w_sT'_s} \times \frac{w_sT_s}{w_cT_c} = \frac{W'_c}{W'_s} \times \frac{W_s}{W_c} = \frac{T'_c}{T'_s} \times \frac{T_s}{T_c}$$

TABLE OF RESULTS.

NON-INDUCTIVE TESTS.

Cable	R_c/R_s	R'_c/R'_s	$\dfrac{R'_c/R_c}{R'_s/R_s}$
1	1.07	1.11	1.06
3	1.22	1.09	.88
4	1.25	.86	.68
5	1.21	.50	.41
6	1.14	.48	.42
7	1.13	.64	.57
Solid, No. 14	1.00	1.00	1.00

INDUCTIVE TESTS.

1	1.01	1.42	1.41
2	1.34	.85	.70
3	1.19	.65	.55
4	1.24	.62	.48
5	1.21	1.11	.92
6	1.24	.36	.29
7	1.92	.61	.32
Solid, No. 12	1.00	1.00	1.00

COMMENTS ON THE TESTS AND THE DATA.

The method employed in obtaining the above tabulated results was entirely experimental and was so devised that no correction factors are required. An examination of the method employed in calculating the results which are recorded above will show that the accuracy of all these relative values is independent of the current measurements. The precision rests only on the measurements of temperature, as all other factors entering the computations cancel out. We believe the final results are accurate to a degree that the maximum variation from the mean obtained in any of the tests on the various cables does not exceed 2 per cent.

The copper cables selected for the tests were chosen from among those which are largely used commercially, especially in the secondary windings of high-tension transformers designed for radio work.

The frequency obtained and used in the tests on the non-inductively wound coils was 250,000 cycles, and the effective value of the high-frequency current obtained and measured as above described was 10.5 ampères. When the coils being tested were wound inductively the inductance, added to the secondary winding of the oscillating circuit, changed the constants of the circuit so that the frequency then became 167,000 cycles and the effective value of the current became reduced to 4 ampères.

When the direct-current tests were made, to determine the constants of the bulbs and their contents, it was found that 19.5 ampères direct current was required to produce the same temperature rise in the same time as that obtained in the high-frequency test, provided non-inductive coils were used, and 9 ampères when inductive coils were used.

When in the high-frequency tests the non-inductive coils were short-circuited the measured high-frequency current was increased about 10 per cent. As the ohmic resistance of the coils was very

small, this indicates that even in the non-inductively wound coils there still remained an appreciable inductance. This may be in part accounted for by the internal magnetic field which exists in every conductor and which no non-inductive winding can eliminate.

The non-inductive coils of cable No. 7 were compared with similarly wound coils made of No. 14 B. & S. solid wire, while the inductively wound coils were compared with similarly wound coils of No. 12 B. & S. solid wire.

The fact that cable No. 1, the strands of which run parallel, heats more than a solid wire of very approximately the same diameter is noteworthy.

The effect of the shape of the cross-section of the conductor on the heat loss is well shown in the tests made on cable No. 5, the cross-section of which was rectangular.

A test was made to compare the losses in two solid-wire coils, one being wound inductively and one non-inductively. The two coils compared were two of the standard coils of No. 12 wire, the one being wound non-inductively and the other being wound in the form of a one-layer helix. The loss in the helix was 2.1 times the loss in the non-inductively wound coil. This rather surprising result may possibly be accounted for by the surging in and out of current in the distributed capacity of the inductive coil, which probably greatly differed from that of the non-inductive coil.

Tests with 60-cycle alternating current were made on all the cables, and with this low frequency no difference could be found between the loss in a cable and the loss in a solid wire, provided the direct-current resistances of both were the same.

CONCLUSIONS.

The following conclusions may be drawn from these tests:

In a cable the strands of which are parallel the loss is appreciably greater than it is in a solid wire having the same cross-section; and, surprising as it may appear, if this same cable is very much twisted, so that the wires lie in concentric spirals, the loss decreases 50 per cent. or more and becomes less than in a solid wire. The tests appear to show that the more the cable is twisted the greater is the reduction in the loss.

With the exception of the case just mentioned, the alternating-current resistance of a cable is less that that of a solid wire of the

same cross-section. The smaller the individual wires and the better they are stranded or braided and the more perfectly they are insulated from each other, the more nearly does the alternating-current resistance approach the direct-current resistance for a given cable. It is, further, important that individual wires should be stranded or braided so that in passing along the cable an outside wire becomes an inside wire, and then again *vice versa*.

Well-insulated cable-strands are obtained by using enamelled wire, though good insulation may be partially obtained by thoroughly treating the cable with an insulating varnish. Our tests seemed to indicate that the decrease in loss obtained by using enamel-insulated wire in cables would hardly warrant the extra cost of this kind of insulation, particularly in cases where only a portion of the total current which flows is high-frequency current. A case of this character is where the secondary of a high-tension transformer feeds an oscillating circuit, some of the high-frequency oscillating current finding its way into the secondary winding of the transformer.

The phenomena which we have attempted to examine experimentally are so exceedingly complicated and are dependent upon so many variables that full explanations of their causes or the drawing of general conclusions are practically impossible. It is hoped, however, that the method here described will enable others, by employing it, to obtain specially-desired data for particular cases and, also, that enough data on typical types of cables are here given to be of much assistance to the designer of high-frequency apparatus in making a selection of a particular type of cable best suited to meet special requirements.

The writers of this paper wish to express their indebtedness to Mr. C. G. Monteiro for the full share which he had in the experimental work and in the taking of the observations.

BOOKS AND ARTICLES REFERRED TO.

[1] George W. Pierce, "Principles of Wireless Telegraphy," chapters 20–21.
[2] J. J. Thomson, "Electricity and Magnetism."
[3] J. H. Dellenger, "High-frequency Ammeters," Reprint No. 206, *Bulletin U. S. Bureau of Standards.*
[4] George W. Pierce, "Principles of Wireless Telegraphy," p. 220.
[5] Edwin F. Northrup and John R. Carson, "The Skin Effect and Alternating-current Resistance," JOURNAL OF THE FRANKLIN INSTITUTE, February, 1914.

PALMER PHYSICAL LABORATORY, Princeton, N. J.,
March 27, 1916.

The Sanitation of Railway Cars—Ventilation. T. R. CROWDER. (*Proceedings of the New York Railroad Club,* April 21, 1916.)—Ventilation is a vital sanitary problem. Good air is of prime importance to good health. Ten or twelve years ago attempts to supply good air to railway cars were generally failures. The problem seemed complicated and almost hopeless. It still has its difficult points, but, thanks to the enlightening research of the last ten years, it is much simplified. We have learned what good air is: it is air that bears a proper thermic relation to the body. It must be able to absorb the body heat as rapidly as formed, without being cold enough to produce chilling. It must be warm, but not too warm; it must have motion, but not enough to cause discomfort; it must be changed occasionally to prevent stagnation and overheating. When these conditions, which are purely physical, are complied with, practically all other things may be left out of consideration. The chemical changes brought about by respiration are ordinarily negligible.

Due to the high wind pressure to which running trains are constantly subjected, a surprising amount of air enters them, even when no special provision is made for it. Apparently the quantity can always be kept adequate by the application of a simple exhaust system, as is now done on many lines. A more difficult problem than maintaining the air supply is the proper control of heat. If the temperature is carefully regulated to between 65° and 70° F., complaint of poor ventilation will seldom arise, even with impure air and a very small supply. Above 70°, trouble comes quickly; we think there is not enough air to keep our lungs flushed out. This is not the trouble at all, for let the air supply remain unaltered and the temperature drop to the lower sixties and we think there is too much. The income and outgo create air motion within. When the temperature is high we need more motion, hence a larger air supply to keep the body cool; when it is low we need less motion, or a lower air supply. But the lungs and the function of respiration have nothing to do with this; it is entirely a surface function; and that is what ventilation is for—to act on the surface of the body and carry away its heat. That is what a fan does, and we all know the virtues of a fan.

With a simple exhaust system of ventilation, specific air inlets are not necessary unless the cars are greatly crowded. Natural crevices, to which may be added open sashes in the end doors, will be sufficient. For supplying artificial heat, direct radiation is better than indirect. Little cold streams of incoming air, mixing with the warmer and stiller body of air within, contribute to the stimulating variation of surface environment which are necessary to comfort and health. Only when larger quantities of air are admitted at one place is heating of the incoming stream desirable, and this is not a good plan for ventilating railway cars. When no artificial heat is needed, as in the warm summer months, nothing can take the place of open windows; for large streams of rapidly moving air are necessary to maintain the thermic balance of the body.

SOME PROBLEMS IN PHYSICAL METALLURGY AT THE BUREAU OF STANDARDS.*

BY

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INTRODUCTION.

THE available knowledge concerning the properties of metals and alloys and the dependence of these properties upon what we may call the life-history of these metals, including their pedigree, or preparation and composition, and conditions of birth, or their manufacture, is all too meagre, both in quantity and quality.

Thus Prof. H. Le Chatelier, who compiled the data on metallic alloys for the Table of Physical Constants recently published by the French Physical Society, prefaces his compilation with the following remarks:

"Concerning the physical properties of alloys, it is impossible to find numerical data worthy of any confidence. This comes from the fact that, on the one hand, experiments have been made by physicists too disdainful of chemical analysis, and, on the other hand, by chemists unfamiliar with physical measurements. It would be impossible in some cases to repeat, to within 50 per cent., results which were measured nevertheless with a precision of one in a thousand, on account of lack of sufficient indications as to the composition of the alloy studied; again, several measurements made on alloys of exactly determined composition do not agree among themselves to 10 per cent. It is practically only for the melting-points of alloys that we possess somewhat accurate information."

This statement by Prof. Le Chatelier is by no means an exaggeration, and that such conditions as he describes with respect to the metallic alloys may exist appears to be due, in part at least, to the isolation and specialization of investigations, and to a lack of appreciation of the importance of the history of the materials

* Presented for Dr. Burgess at a meeting of the Mining and Metallurgical Section held Thursday, March 30, 1916, by Dr. Paul D. Merica.

which are being studied. How many precise physical measurements, for example, have been made on material described merely as "iron," the results of which are oftentimes meaningless because of lack of a sufficient and necessary knowledge of chemical composition, mechanical treatment, and thermal history?

TABLE I.

Investigation and Testing of Metals at Bureau of Standards.

PUBLICATIONS: T = Technologic Paper, S = Scientific Paper, C = Circular of Information; referred to by number.

A. MATERIALS..... C 45

1. *Metallic Elements:* Iron, nickel, copper, zinc, etc.
2. *Alloys:* *a.* Two components: Iron-carbon (steels), copper-zinc (brasses), etc.
   b. Three or more components: Alloy steels, complex bronzes and brasses, etc.
   c. Commercial metal alloy products.
3. *Plated Metals:* Galvanized iron, copper and nickel plating, etc.
4. *Auxiliary Products:* Metallurgical slags, fire-clays, moulding sands, deoxidizers, etc. C 45; T 10.
5. *Apparatus:* Instruments, manufacturing accessories, furnaces, etc. S 219.

B. METHODS:

1. Preparation illustrated by:
   a. Production of Pure Metals: Examples, electrolytic iron, gallium, etc. S 263.
   b. Standards for Pyrometry, Electricity, chemical analysis, metallography, etc. S 107, 143, 194, 195, 256; C 1, 2, 3, 7, 14, 18, 25, 26.
   c. Mixing Pure Metals (in foundry and laboratory): Examples, pure iron-carbon series, Government bronze (88 Cu − 10 Sn − 2 Zn), etc. T 59.
   d. Treatment of Alloys: Thermal, chemical, mechanical, magnetic, electric, etc. C 6, 17, 42; T 60.
   e. Commercial Samples, including methods of sampling.
   f. Coöperative Production and Tests on a Commercial Scale: Examples, ingots for rails, structural brasses and bronzes, statuary bronze, moulding sands, test ingots of steel, etc.

2. Constitution as determined by: C 42
   a. Chemical Analysis: Bureau is equipped for chemical analysis of all metal products: Example, segregation in steel and bronze ingots, T 6, 8, 24, 33, 69; S 161, 186; C 14, 25, 26, 42.
   b. Thermal Analysis: Heating and cooling curves for location of melting and critical points: Examples, alloy steels, new alloys, etc. S 99, 213; C 7. Variation of physical properties with temperature.
   c. Microscopic Analysis (*i.e.*, characteristic microstructure as determined by)
      1. Chemical composition.
      2. Thermal history.
      3. Mechanical work, hot or cold.
      4. Manufacturing methods.
      5. Metallographic methods and apparatus, etching reagents, etc.; photomicrographs furnished.

2. Constitution as determined by: C 42
- *d. Other Physical Methods of Examination:* Examples, expansion, thermo-electric, magnetic, spectroscopic, etc. S 19, 108, 109, 117, 120, 251.
  1. Thermo-electric determination of platinum purity. S 254, 280.
  2. Spectroscopic analysis for rare elements in steels.
- *e. Nomenclature*
  1. Non-ferrous alloys.
  2. Constituents of steel.

3. Properties.....
- *a. Chemical and Physico-chemical:* Examples, solubilities, attack by acids, improvement of analytical methods, etc. S 53, 82.
- *b. Physical* at high, ordinary, and low temperatures:
  - 1. Mechanical.....
    - Density.
    - Hardness. T 11.
    - Fatigue.
    - Tensile, etc.
    - Elastic.
    - Torsion, shear, etc.
    - Bending.
    - Hydraulic.
  - 2. Thermal.....
    - Melting-point. S 62, 143, 205; C 35.
    - Critical point. C 7; S 236, 213.
    - Specific heat. S 231.
    - Heat of fusion.
    - Heat of vaporization.
    - Conductivity. S 68.
    - Expansion, etc.
  - 3. Electrical, magnetic, optical:
    - Capacity, etc. S 64; 252.
    - Resistance. S 73, 94, 124, 147, 148, 236.
    - Thermo-electric. S 229.
    - Susceptibility, etc. S 252.
    - Permeability. S 38, 78, 80.
    - Radiation. S 24, 40, 55, 105, 121, 128, 131, 156, 191.
    - Absorption.
    - Emissivity. S 97, 152, 196, 224, 242, 243.
    - Etc.
- *c. Miscellaneous.* T 2, 15; C 58; S 272.
- *d. Effect of Impurities:* Examples, occluded gases, slag, oxides, cadmium in brass, etc. T 6, 8, 24; S 161,
- *e. Effects of Outside Agencies; i.e.*, pressure, magnetic field, etc.
- *f. Corrosion...*
  1. Iron and steel.
  2. Brasses, etc.
  3. Structures. T 15.
  4. Electrolytic surveys of cities, etc. T 25, 26, 27, 28, 32, 52, 54, 55.

4. Applications...
- *a. Built-up Structures:* Examples, bridge columns. T 2.
- *b. Substitutes for More Costly Metals.*
- *c. Miscellaneous Improvements.* C 50, 51, 52.
- *d. Metals Best Adapted for Given Purpose.*
- *e. Effect of Time in Testing Operations.*

5. Manufacturing processes
- *Replies* to innumerable requests for information. T 38.

6. Metallurgical processes and treatments, such as theory and practice of:
   - *a. Annealing:* Examples, ordnance, bronzes, cast iron.
   - *b. Forging and Rolling:* Examples, rails, axles, etc.
   - *c. Tempering:* Example, springs.
   - *d. Quenching and Hardening:* Example, various steels.
   - *e. Cementation:* Example, automobile parts.
   - *f. Cold and Hot Working:* Examples, steels and bronzes.
   - *g. Casting:* Examples, rail ingots, various alloys.
   - *h. Plating, etc.:* Examples, copper, zinc, tin, nickel, etc.
   - *i. Alternating Stress.*
   - *j. Welding:* Examples, castings, rails.
   - *k. Miscellaneous:* Examples, finishing temperatures of rails. T 38. Coatings for metal structures.

7. Special problems, such as
   - *a. Electric Fuses.* T 74.
   - *b. Bonding of Rails.* T 62, 63.
   - *c. Improvement of Locomotive Springs.*
   - *d. Transverse Fissures in Rails,* investigated by (as example of methods used):
     1. Mechanical.
     2. Thermal.
     3. Optical.
     4. Chemical.
     5. Metallographic.
     6. Magnetic.
     7. Statistical.
     8. In coöperation with railroads.

8. Specifications for:
   - *a. Government Departments.*
   - *b. Cities, Commissions, etc.*
   - *c. In Coöperation with Technical Societies.*
   - *d. In Response to Private Requests.*
   - *e. Compilation of:* Examples, foreign specifications of railway materials. T 61.

9. Metal failures, determination of causes such as of:
   - *a. Railway Materials:* Rails, wheels, axles, etc.
   - *b. Castings:* Forgings, etc.
   - *c. Structural Bronzes and Brasses:* Examples, Catskill Aqueduct bronzes.
   - *d. Fusible Boiler Plugs,* for Steamboat-Inspection Service. T 53.
   - *e. Miscellaneous:* Boiler plates, tubes, galvanized ware, etc.

10. Testing: Includes items in all of above schedule.
11. Correspondence and advice given on all of above items.
12. Compilation of physical constants of metals.
13. Bureau serves as referee in disputes concerning metals.

14. Coöperation with technical and scientific societies, such as committees of:
   - *a. American Chemical Society.*
   - *b. American Society for Testing Materials.*
   - *c. American Foundrymen's Association.*
   - *d. American Institute of Metals.*
   - *e. American Electrochemical Society.*
   - *f. American Society of Civil Engineers.*
   - *g. American Institute of Mining Engineers.*

15. Metal Museum: *Exhibits of Metals.*

In planning an experimental attack on any comprehensive problem in physical metallurgy it is therefore essential to keep constantly in the foreground the interrelations of those various

factors dependent upon manufacture and previous history of the material studied; which is another way of saying that while physical metallurgy may be said to be that branch of science which treats of metals in their physical aspects, yet it takes cognizance also of chemical metallurgy—the only metallurgy of a few years ago—chemistry and physical chemistry including crystallography and metallography, and expresses itself largely in the language and uses the instruments of physics. At the Bureau of Standards, in planning our investigations of metals, we have striven, in so far as the several problems permitted, to treat them in such a manner that none of these essential factors or aspects is omitted.

In Table I is given a summary of the various activities relating to metals that have been executed or are being carried out at the Bureau. Each of the items mentioned has been or now is an object of experimental study on the part of one or another of the several scientific and technical divisions into which the Bureau, for administrative reasons, is divided.

It is, of course, not my intention to tax your patience with a detailed account of the progress made in all of these items of research, testing, specifications, and other matters relating to metals at the Bureau of Standards. As illustrative of our methods, however, I will venture to sketch, as briefly as possible, certain of these problems, with the solution of which it has been my privilege to have been, in some measure, personally identified.

PREPARATION AND PROPERTIES OF PURE IRON.

Iron, in its various alloyed forms, is perhaps the most commonly used of the metals, and yet few of us have even seen, and much less worked with, *pure* iron. It would appear to be almost axiomatic that for a comprehensive knowledge of the iron alloys it is first necessary to know with some exactness the properties of the major constituent, the iron itself. Yet here for this most common metal Le Chatelier's admonition is strikingly true: our knowledge of the physical properties of this ordinary and extraordinary chemical element is highly imperfect and very unsatisfactory.

To prepare this metal of a high degree of purity and determine at least some of its physical properties with exactness was, therefore, one of the first fundamental problems which the Bureau of Standards set itself in its study of metals. This is being followed by similar studies of the iron alloys of carbon, manganese, etc.,

free from the other contaminating elements usually, or practically always, present in such steels or alloys made by the ordinary industrial processes.

But it was soon found that in the preparation of strictly pure iron, say 99.97 per cent. Fe, it was no simple matter to eliminate certain of the impurities from this material and to prevent contamination by others. The iron deposited electrolytically, which was used as a basic material, can be broken in the hands, is cellular, and contains hydrogen; so the metal had to be heated and melted *in vacuo* to expel this and other gases. As no crucibles could be found on the market which were sufficiently free from silica to prevent contamination of the iron during the melting operation, methods had to be devised to make especially purified and calcined magnesia, which was then made up into crucibles to melt the iron in.[1] We are not yet sure regarding the oxygen content of this iron, which has indeed become a precious metal. A special study has, however, been begun of this puzzling question of the presence and significance of gases and oxides in iron and steels.

The pure iron thus made available, even in quantities of only a few grammes, can now be compelled to give an account of itself as to its several physical properties. This examination is under way, and the correct experimental bases for the answer to several questions long in dispute or doubt concerning the properties of pure iron have been laid in our laboratories or in others to which samples of the iron prepared at the Bureau of Standards have been sent.

Thus we have determined the melting-point of pure iron to be $1530° \pm 3°$ C.,[2] and have located with improved apparatus and described the thermal, critical ranges or transformations A_2 and A_3, at 768° C. and about 910° C., concerning the nature and very existence of A_2 at least, and the interpretation of which, in terms of allotropy, there has raged a discussion covering at least three decades.[3] The exact form of curve of variation of electrical resistance with temperature between 0° and 950° C. has been

[1] Cain, Schramm, and Cleaves, "Preparation of Pure Iron and Iron Carbon Alloys," B. S. Scientific Paper No. 266, 1915.

[2] Burgess and Waltenberg, "Melting-points of the Refractory Elements: I. Elements of Atomic Weight 48 to 59," B. S. Scientific Paper No. 205, 1913.

[3] Burgess and Crowe, "The Critical Ranges, A_2 and A_3, of Pure Iron," B. S. Scientific Paper No. 213, 1913.

measured with high accuracy,[4] and there is under way a study of the thermo-electric characteristics over the critical ranges A_2 and A_3, which confirms their separate existence and different nature. Measurements of the specific radiation for the solid and liquid over a wide temperature interval are among the other physical constants of iron thus far determined. The specific heat, heats of fusion and vaporization, and magnetic properties are waiting their turn with many others. In the hands of Professor Honda, of Japan; Professor Carpenter, of London, the staff of the Geophysical Laboratory, and several other investigators, this iron made by us is yielding other very interesting and valuable results.

APPLICATIONS OF THE MICROPYROMETER.

When dealing in investigation work with the more common metals, such as iron and copper, the difficulty hardly ever arises of scarcity of materials, such that our work with them may be carried out on specimens of as large size as desired. In the case, however, of certain metals and materials we may consider ourselves fortunate in being able to obtain even the smallest quantities of them. In studying the properties of such small amounts special methods have to be devised. As an instance of such a method which has been developed at the Bureau may be mentioned the

Emissivities of Metals and Oxides with Micropyrometer.

Metals		Cu	Ag	Au	Pd	Pt	Ir	Rh	Ni	Co	Fe	Mn	Ti
$e\lambda = 0.65$	solid	0.10	0.04	0.14	0.33	0.33	0.30	0.29	0.36	0.36	0.37	0.59	0.63
	liquid	.15	.07	.22	.37	.38	.....	.30	.37	.37	.37	.59	.65
$e\lambda = 0.55$	solid	.38	<.35	<.38	.38	.38	.....	.....	.44	.....	.....	.....	.75
	liquid	.36	<.35	<.38	.....	.....	.....	.....	.46	.....	.....	.....	.75

Metals		Zr	Th	Y	Er	Be	Cb	V	Cr	Mo	W	U	
$e\lambda = 0.65$	solid	0.32	0.36	0.35	0.55	0.61	0.49	0.35	0.39	0.43	0.39	0.54	.....
	liquid	.30	.40	.35	.38	.61	.40	.32	.39	.40	.....	.34	.....
$e\lambda = 0.55$	solid	.....	.36	.....	.....	.61	.61	.29	.53	.....	.....	.77	.....
	liquid	.....	.....	.....	.30	.81	.....	.....	.....	.....	.....	.....	.....

Oxides near F. P. s.		NiO	Co_3O_4	Fe_3O_4	Mn_3O_4	TiO_2	ThO_2	Y_2O_3	BeO	CbOx	V_2O_3	Cr_2O_3	U_3O_4
$e\lambda = 0.65$	solid	0.89	0.77	0.63	.....	0.52	0.57	0.61	0.37	0.71	0.69	0.60	0.30
	liquid	.68	.63	.53	0.47	.51	.69	.....	.....	.....	.....	.....	.31

[4] Burgess and Kellberg, "Electrical Resistance and Critical Ranges of Pure Iron," B. S. Scientific Paper No. 236, 1914.

micropyrometer,[5] with which the melting-points of many refractory metals, alloys, and oxides have been determined, as well as their specific radiation (emissivity) and its dependence upon temperature, using only a few milligrammes of the substance studied.[6] It is hoped to be able soon to publish the melting-points of all the refractory chemical elements.

Some of the results of emissivity and melting-points thus obtained with the micropyrometer, using less than 0.01 milligramme of the materials, are here tabulated.

Melting-points of Refractory Elements with Micropyrometer.

Mn	Co	Y	Cr		Fe	Zr	Cb	V
1260	1480	1490	1520 to	>	Fe	1530	(1600)	(1650)	1720

Ti	U	Rh	Th	Ir	Ru	Mo	Os
1800	(1850)	1960	(2350)	(2400)	(2450)	(2500)	(2650)

The values in parentheses are of considerable uncertainty on account of doubt as to purity or of difficulty of melting-point determination.

A considerable number of melting-points—particularly " fixed points " in thermometry and pyrometry—have been determined by other methods, notably by the use of the electrical resistance, thermo-electric, radiation, and optical pyrometers.[7] A study has also been made of the methods of thermal analysis.[8] Other methods have also been applied to the determination of the radiation characteristic of several substances, such as copper and its oxide [9] and the oxides of iron [10] and nickel.[11]

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[5] Burgess, " A Micropyrometer," B. S. Scientific Paper No. 198, 1912.

[6] Burgess and Waltenberg, " The Emissivity of Metals and Oxides: II. Measurements with the Micropyrometer," B. S. Scientific Paper No. 242, 1915.

[7] Waidner and Burgess, " Radiation and Melting-points of Pt and Pd," B. S. Scientific Paper No. 55, 1907; " Platinum Resistance Pyrometry at High Temperatures," B. S. Scientific Paper No. 124, 1909; " Note on the Temperature Scale Between 100 and 1500° C.," B. S. Scientific Paper No. 143, 1910.

[8] Burgess, " Methods of Obtaining Cooling Curves," B. S. Scientific Paper No. 99, 1908.

[9] Burgess, " Estimation of the Temperature of Copper by Means of Optical Pyrometers," B. S. Scientific Paper No. 121, 1909.

[10, 11] Burgess and Foote, " Emissivity of Metals and Oxides: I. Nickel Oxide," B. S. Scientific Paper No. 224, 1914; " IV. Iron Oxide," B. S. Scientific Paper No. 249, 1915.

QUALITY OF PLATINUM WARE.[12]

Another type of metal problem, in which the application of physical methods to the solution of a question of interest, this time primarily to chemists, and which came to us through a committee of the American Chemical Society, has been productive of interesting results; namely, that of the determination of the purity and quality of platinum ware, and especially of crucibles. An analysis which leaves the crucible intact and which also indicates the weight it loses on heating was the desideratum.

Applying well-known thermo-electric principles, it has been found to be easily possible to classify platinum of different degrees of purity, and by executing a series of heatings under exactly defined conditions at several temperatures the data necessary for the solution of the problem have been accumulated. Incidentally, from the examination of several hundred platinum utensils an idea of the quality of the platinum ware on the American market has been obtained, and the purchaser of platinum is now in a position to buy intelligently, using specifications which can be checked without injuring the articles purchased if he so chooses. The main experimental results of this investigation may be summarized briefly as follows:[13]

All platinum carries iron as impurity, which, diffusing to the surface and oxidizing on heating, tends to increase the crucible weight and mask the volatilization losses. These losses for platinum nearly free from iron, expressed in mg./100 cm.^{2}/hour at the temperatures indicated, are shown below:

Platinum containing	Pure Pt	1 per cent. Ir	2.5 per cent. Ir	8 per cent. Rh
900° C. or less	0	0	0	0
1000	0.08	0.3	0.57	0.07
1200	0.81	1.2	2.5	0.54

Platinum crucibles should be made, therefore, free from iron and iridium, and should contain a small percentage of rhodium. Further investigations may possibly demonstrate the superiority of platinum crucibles alloyed with osmium.

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[12] Burgess and Sale, "A Study of the Quality of Platinum Ware," B. S. Scientific Paper No. 254, 1915.

[13] Burgess and Waltenberg, "Further Experiments on the Volatilization of Platinum," B. S. Scientific Paper in press.

COÖPERATIVE INVESTIGATIONS.

The Bureau of Standards carries on a large proportion of its researches in coöperation or after consultation with committees representing the several scientific or technical societies of the country interested in the particular subject. Oftentimes, as just noted in the case of platinum, a particular investigation is undertaken at the request of one or several societies or other representative technical body. The unfulfilled requests of this nature concerning metals alone would keep the whole Bureau staff busy for several years. This coöperation in laying out the work is a very excellent arrangement to both parties, the public and the Bureau, as it is evident that the Bureau gets a broader outlook upon any given problem than it could otherwise have, and it is certain, in its endeavors to solve the problems asked for, of the most hearty cooperation and advice of those most competent in the matter.

There is, for example, an Advisory Committee on Non-ferrous Alloys, composed of representatives of the several societies interested, which meets twice a year at the Bureau, and the frank interchange of ideas concerning the several problems has been most useful to all concerned. This is one of several such committees.

A problem thus handled is that of Standard Test Specimens of the Zinc Bronze 88 Cu–10 Sn–2 Zn, involving a systematic study of the variations of the different factors in foundry practice which might be expected to influence the quality and properties of the test specimen. This is accompanied, also, by investigation of the physical properties and their changes under varying conditions of production of the alloy. As a corollary has been carried out a study of the microstructure of this alloy which showed oxidation between crystals to be the most important source of detrimental effect on its properties,[14] as well as a study of structural changes accompanying heat treatment and mechanical work upon the alloy.[15] This may be said, therefore, to be a typical problem in physical metallurgy involving and correlating all the various factors mentioned at the outset of this paper, on a widely-used alloy commonly known as Government bronze.

[14] Karr and Rawdon, "Standard Test Specimens of Zinc Bronze 88 Cu–10 Sn–2 Zn," B. S. Technologic Paper No. 59, 1916.

[15] Rawdon, "Microstructural Changes Accompanying the Annealing of Cast Bronze," B. S. Technologic Paper No. 60, 1916.

Many are the riddles in metals propounded to us by the several departments of the Federal Government and not a few, also, by state commissions and municipal bodies. As an illustration may be cited the investigation of tin fusible boiler plugs,[16] made at the instance of the Secretary of Commerce for the Steamboat-inspection Service. This is a device for preventing boiler explosion by the melting of a tin filling enclosed in a bronze casing screwed into the boiler between fire and water. Investigation showed, among other things, that plugs of impure tin, especially those containing zinc even as low as 0.3 per cent., will deteriorate, and the tin may finally all go over to oxide which melts at a temperature higher than the steel of the boiler, thus causing the plugs to become a source of danger, not of safety. In the course of this investigation over 1000 plugs—new and used—were examined and many interesting facts brought to light.

STUDY OF STRUCTURAL BRASSES.[17]

Many investigational problems have been taken up at the Bureau as the result of tests made for private firms or public service boards. Such tests oftentimes reveal hitherto unexplained characteristics of materials or sources of defects in them which seem to warrant much further investigation. An illustration is the study of the failure of structural brass by season-cracking or in similar manner. This work was taken up as a result of certain tests made for the New York Board of Water Supply of failed brass materials supplied them for use in the construction work of the Catskill aqueduct. These brasses, consisting mostly of so-called manganese bronze, of a total amount of approximately 3,000,000 pounds, were installed in the form of castings, forged and wrought bolts, ladders, etc., and to date an alarming percentage of failures has occurred among these materials.

It was early thought that the presence of internal, initial stresses in these materials might account for the failures which have occurred. Such stresses are introduced during the processes of manufacture, either during the cold working or as a result of unequal cooling of different parts of an article, and are generally,

[16] Burgess and Merica, "Investigation of Fusible Tin Boiler Plugs," B. S. Technologic Paper No. 53, 1915.

[17] Merica and Woodward, preliminary publication, *Proc. Am. Inst. of Metals*, 1915.

but not always, found as a result of attempts to obtain undue hardness in the brass.

To date some 250 samples of the type of brass in question have been investigated in the attempt to correlate failures with the presence of these internal stresses, and these, in turn, with the physical properties, such that engineers may have some data upon which to formulate in the future their specifications for such materials in order to avoid the danger of the repetition of this type of failure on such a large scale.

Several subsidiary investigations on brass have also arisen, such as the stresses developed in castings on welding or "burning-in," and the effect on the properties of the material of the presence of minute quantities of certain impurities, as cadmium.

Another very practical problem being studied at the Bureau is the question of the properties and quality of electro-deposited copper in connection with electrotyping and similar work. Studies are being made of the mechanical properties as affected by the conditions of deposition, etc., and in correlation with the study of the micro-structure.

COOPERATION WITH MANUFACTURERS.

The Bureau has been particularly fortunate in having had placed at its disposal without restriction the facilities of manufacturing plants, such as of brass and steel manufacturing companies, for the carrying out of investigations, the execution of which would have been otherwise impossible except at enormous and practically prohibitive expense. This has made possible, for example, the investigation of finishing temperatures and properties of rails,[18] a problem not yet completely solved and in which many other factors are involved, and one which gave us the opportunity of demonstrating the practicability of pyrometric control of rolling-mill operations.

Another investigation in which there could have been no considerable advance without hearty coöperation on the part of steel manufacturers is the sound ingot research, about which there has been some preliminary publication,[19] which is still in progress.

[18] Burgess, Crowe, Rawdon, and Waltenberg, "Finishing Temperatures and Properties of Rails," B. S. Technologic Paper No. 38, 1913.

[19] Hadfield and Burgess, "Sound Ingots and Rails," *Am. Inst. of Mining Engrs., Feb.*, 1915. *Journ. Iron and Steel Inst.*, May, 1915.

The same is, of course, true of the investigation under way to determine the best type of "test ingot" to use in sampling steel for analysis, an investigation in coöperation with the American Society of Testing Materials.

Another problem may also be mentioned which is nearing solution and for which we have used several steel plants as laboratories; namely, the pyrometric control of steel furnace and pouring operations. The results thus far obtained indicate the possibility of exact measurement of temperatures of pouring steel and a reasonably precise control of the open-hearth furnace operations.

Here it seems appropriate to refer at least to a feature of our work which we highly prize, and one which is to us most valuable; namely, the fact that work done at the Bureau, because of its public origin, very often incites discussion, both oral and written, which may be of greater value than the main plan itself, and brings thus to light facts and experience that might otherwise pass unnoticed. Our experience has in this respect been most happy, and many manufacturers, for instance, with whom we have had the pleasure of dealing have had a most generous array of practical experience to offer in comment on certain phases of work in which the interest has been common.

METAL FAILURES.

The Bureau, as indicated above, does a great deal of investigation of failed material, and some of the cases studied present varied points of interest, and also illustrate the present-day method of metal and metallurgical investigation. A word about the failure of metals in general may, therefore, not be out of place.

The question of metal failures is a very comprehensive one and, indeed, may be said to embrace all cases in which a metal does not fulfil as well as may be the use or uses to which it is put Whether or not a metal is a failure under given conditions may, therefore, be a relative matter, and there cannot usually be an ideal standard of service—for example, *all* steel rails eventually wear out, and so, in a sense, all such rails finally fail to perform the duty imposed upon them, but a rail lasting several years or months, as the case may be, is apparently to be classed as a sound rail as compared with one in which a flaw develops soon after laying in the track. The rail which has stood up well may, nevertheless, not be a sound one. It may possess a hidden defect, originating in the

ingot from which it was rolled, and which may eventually bring about a sudden collapse causing accident. Or, again, the changes in the conditions of train service in the track, such as heavier locomotives or its upkeep, may have occurred, resulting in a rail failure due to too severe service conditions or insufficient care of the road-bed or ties.

Of metals we may say then, as of men, some are born failures, some acquire failure, and others have failure thrust upon them. Fortunately for the metals, some cases, but not all, of "born failures" may be cured, either by amputation or treatment, if the subject is taken in hand early enough in its career.

Metal failures may evidently be classified as to type or cause, whether due to inherent chemical or physical imperfections or to some incorrect treatment, as thermal, mechanical, or chemical, which it may have received either in manufacture or subsequently.

Several well-known methods of detecting failures and studying failed metals have been developed. It is often necessary, also, in studying metal failures, to fix the responsibility, and it may be necessary at times to decide whether the fault is in the metal or in the specifications, which may have been so incorrectly or inadequately drawn as to be entirely unsuited for the metal in question—the metal has had failure thrust upon it. This happens more frequently than is perhaps generally appreciated, and a very notorious example of this has occurred in the search for a non-corrodible metal as strong as steel—with the result that manganese bronze in engineering construction may be said at present to be on the blacklist.

The question of tolerances in chemical composition—for instance of many types of steel and of certain non-ferrous alloys—is oftentimes a puzzling one and introduces complications in the endeavor to apportion blame for the failure; and the acceptance or rejection of alloys of stated and complex composition on chemical analysis—the legitimate prevention of failure in those cases for which the relation of composition to performance is really known, which it seldom is adequately—is oftentimes shrouded in mystery and encircled with doubt. There is a great deal of uncertain knowledge—or certain ignorance, as you will—all about this aspect of chemical composition and its relation to the subject of metal failures and their prevention.

For example, let us look at the supposed chemical safeguards

thrown about the acceptance of steel rails in various countries avowedly with a view to prevention of their failure. The United States and Great Britain, of which metallurgically we may be said to be a colony, specify narrow or maximum limits for the elements carbon, manganese, phosphorus, silicon, and sulphur; and yet statistics show, I believe, relatively the most rail failures in the United States and nearly, if not quite, the least in Great Britain. Therefore, one might argue, as do the German and French apparently, the chemical analysis means nothing as to ultimate behavior of the rails. The question of dual requirements, both chemical and physical, in specifications is always with us, and I do not mean to more than call your attention to it in this discussion of failures. There is one aspect of the rôle of chemical specifications, however, which is evidently of importance; namely, where there is an abrupt change of phase accompanied by marked change in physical properties, as is the case for certain bronzes and brasses as well as steel, it is evidently desirable or necessary to so limit the composition that the alloy will normally be of the desired composition and hence of the properties expected.

For certain uses one or another of the pure metals as distinguished from an alloy has been found desirable. The question then arises: What degree of purity should be insisted upon to avoid failure, and what impurities may be allowed, if any? For each case the answer to this question can be found only by careful investigation and trials in service.

There is one type of failure to which most metals, and particularly metallic alloys, are subject in high or low degree and which is probably the most deadly disease of the metal realm—I mean corrosion—the examples of which would be infinite. Many and varied are the methods employed to ward off this fatal malady, some aspects of which have been studied at the Bureau, but their discussion would take us far afield.

Finally, the analogy of metal failures to diseases is made most complete by the existence of what we may call imaginary ills, such as the supposed metastabilities and allotropies of some of the more common metals, including zinc, lead, and copper—or, in the words of Rosenhain, "allotropy gone mad." Thus for copper has been assigned a phase change at about 70° C. An examination of this metal, however, by the electrical resistance method has convinced us that to at least 1 in 50,000 there is no evidence of

allotropy and consequent metastability in copper between 0° and 100°.[20]

The question which, of course, goes hand in hand with that of metal failures is: their prevention—how may it be accomplished? In many cases the answer is indicated immediately with the determination of the cause of failure. In many others the answer is not at hand with our present knowledge, so that this field of science, as all others, is a prolific one for further research.

With this incomplete statement regarding some general aspects of the question of metal failures, let us now consider some specific examples, taken for the most part from our experience at the Bureau of Standards.

(Several cases illustrated by lantern slides.)

RAILWAY MATERIALS.

A group of materials of which the failure in service is particularly serious is that of railway materials, such as rails, wheels, axles, tires, etc. An investigation of some of the causes of failure in such materials has been started at the Bureau. (A few typical examples of rail failures investigated at the Bureau, including a "flowed rail," piped rails, and transverse fissures were shown in the slides.) A great many of such failures are to be traced directly to the ingot, as was indicated above.

In its study of this subject the Bureau is having the cordial cooperation of the railroads and manufacturers of such material. Several methods of attack are being used, including a comparison of foreign specifications for railroad materials and resulting service as expressed in accident statistics;[21] a survey of the experience of American railroads regarding certain types of failure, as transverse fissures in rails, the behavior, design, service, and typical failures of the several types of car wheel; and these statistical studies are, of course, being supplemented by extended experimental researches now under way, some of which are mentioned above, including sound ingots, the causes of transverse fissures, cracking of car wheels due to braking, and several others.

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[20] Burgess and Kellberg, "On a Supposed Allotropy of Copper," *Jour. Wash. Acad.*, **5**, p. 657, 1915.

[21] Burgess and Merica, "Some Foreign Railway Specifications: Wheels, Rails, Axles, Tires," B. S. Technologic Paper No. 61, 1916.

CONCLUSION.

As is evident from the foregoing, our program in physical metallurgy is a rather ambitious one and the criticism may perhaps be offered, as it has been already, that it is too extensive for the forces, both physical and vital, at our disposal. It may, however, be replied, obviously, that it is not without the bounds of possibility to increase these forces, a condition much to be desired so that Physical Metallurgy may be helped thereby to take a place worthy of its importance in the community and commensurate with the vast metal industries of our country; again, that a considerable number of the important problems now being attacked will eventually be solved along the lines laid down and within a reasonable time may be assured if one notes from Table I the record of publications describing the progress hitherto made in the investigation of metals at the Bureau of Standards.

The Relation Between Contact Potentials and Electrochemical Action. T. LANGMUIR. (*Proceedings of the American Electrochemical Society*, April 29, 1916.)—The history of electrochemistry has been marked by a century-long conflict between the contact theory and the chemical theory of electrochemical action. The modern electrochemist usually considers that this conflict has long been brought to a close by the victory of the chemical theory. He believes that contact potentials between metals are entirely inappreciable. No such uniformity of opinion has existed among physicists. Within the last few years very remarkable work in physics has demonstrated that contact potentials of large magnitude do exist, even between pure metals in a practically perfect vacuum. This evidence, which is reviewed in some detail, has been obtained by a study of (1) electron emission from heated metals; (2) photoelectric phenomena; (3) contact potentials. Several independent methods lead to values of contact potentials which are in substantial agreement.

Much of the difficulty which the electrochemist has had in reconciling the contact theory with the known intimate relation between chemical action and electrochemical phenomena has been due to failure to properly define "potential difference" and "electromotive force." Definitions of these are given and a theory of the mechanism of the effect is developed. It is not necessary to take into account contact potentials when only the electromotive forces of reversible cells are considered. But in dealing with the kinetic phenomena, such as overvoltage and passivity, or with effects due to single potential differences, the contact potential must be an essential factor.

Activity of American Shipyards. J. G. DONANCE. (*Scientific American*, vol. cxiv, No. 22, May 27, 1916.)—Not since the palmy days of the Yankee clipper has there been given to our shipbuilding and shipping, but most of all the former, so real an impetus as they have both received within a few months' time. In 1914 these industries had reached their low ebb here, and it was then that chance interfered to offer American initiative the opportunity to make a change. Vessels of foreign make were beginning to have their registry changed under the act of August 18, 1914, so that some few American shippers began to see their chances, and took them, as did some others who were not either shipowners or shipbuilders, but decided to become so. Their judgment has since been amply justified.

On July 1, 1915, there were building or under contract in American shipyards 46 vessels: between that time and December 1, 52 additional ships were ordered, bringing the total of those under construction up to 761,511 gross tons on the latter date. Of them, 47 were built to hold bulk oil, 34 general freight, 11 were colliers, and 6 for passengers and freight. These figures are a good index as to the character of the present trade.

Deducting vessels lost, abandoned, or sold to aliens up to December 1, there is a net increase of 187 vessels, 53,829 gross tons, in our merchant marine since the 1st of last July. There is now under construction at just four of the leading yards a gross tonnage amounting to 413,000, as contrasted with a total of 316,000 tons for ships built during the year of 1914 and 346,000 for those of 1913. Vessels arriving last year at the port of New York were 10,279 in number, and 9203 the year before. Prices of American-built vessels have advanced 50 per cent. in six months, and labor has enjoyed a corresponding increase. Some of the greatest shipbuilding nations of the world, formerly, are now no longer able to hold their own along commercial building lines. Other countries are stepping into their places. But yet the world production of ships is far below the normal, and manufacturers here are trying hard to make this up.

THE ELEMENT OF CHANCE IN SANITATION.*

BY

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CHANCE is an element with which we have to deal in sanitation just as we have to consider it in studying natural phenomena. This does not mean that events happen without cause, but that there are so many causes of the events that we cannot consider each alone. Given a certain number of causes, these may combine in many ways to produce many events, some of which happen often and some rarely. The frequency with which given events will happen is subject to mathematical analysis according to the theories of probability. We sometimes speak of these as the laws of chance.

Consciously or unconsciously we are making use of these laws of chance in everyday life. Generally we use them in a crude and unscientific way. The business man considers the possibility of certain events happening and adjusts the selling price of his goods accordingly. The stock broker does this on a more elaborate scale. Carried to the limit, his operations become speculation. The whole business of insurance is founded upon the idea of chance. For example, in life insurance, regular annual receipts from the policy-holder are put against the payment of a lump sum at the time of death, and the probability of the number of such annual payments being received before death is used as the basis of determining the rate of insurance.[1] Indeed, in early days, life insurance was regarded as a sort of gambling and at one time was prohibited by law, the risks being considered to be all on one side. Nowadays it is understood that by the proper use of the laws of chance it is possible to make fair adjustments between the insurers and the insured. What really happens is that those who live long pay to the families of the insured who die young, or, as one might say, the strong help the weak, the insurance companies acting as adjusters and, of course, taking a certain part payment for their

* Presented at the meeting of the Mechanical and Engineering Section held Thursday, March 9, 1916.

[1] More strictly, it is the probability of living from one year to another.

services. So it is in fire insurance: those whose insured buildings do not burn pay to those who lose by fire.

The measurement of errors of observations in all kinds of scientific work shows that the small errors occur frequently and that the large errors occur less frequently. The relation between the frequency of occurrence of large and small errors has become known as the "law of error." It is practically the same as the law of variation in natural phenomena. If one measures the heights of a thousand men or the lengths of a hundred oak leaves or the weights of a dozen apples, it will be found that the items when arranged in order of magnitude follow this general law of frequency, and so rigid appears to be the application of the law that, knowing the variations in the heights of a thousand men, it is possible to calculate the frequency with which one may expect to find a dwarf or a giant.

The laws of chance are well known to the gambler, although not expressed by him in algebraic form. It is interesting to remember that some of the first mathematical studies of probability were made for the benefit of gamesters. The frequency with which certain combinations of dice or cards may be thrown has been found to be susceptible of mathematical demonstration, and the mathematical laws deduced from theory have been proved by experiment. The roulette wheel is scientifically planned, and even in the penny-in-the-slot machine, with its pegs and pockets arranged like a bagetelle board, there is a striking similarity between the values of the prizes offered for putting the penny into the different pockets and the normal curve of error. The engineer unconsciously uses the laws of chance when he allows a factor of safety in designing a bridge, recognizing that there is a certain possible chance of unsuspected loading of the span or some unsuspected weakness in the steel. Recently it has been found that annual rainfall records in a given locality follow the general law, so that from a series of records covering only twenty years it is possible to predict the probable maximum or minimum rainfall in a period of 50, 100, or 150 years. This is useful in designing the spillways of dams, and in determining the capacities of sewers. Many other natural phenomena may similarly be shown to be subject to these laws.

Although the laws of chance were developed many years ago by mathematicians and students of the exact sciences, it is in the

realm of biology that the most important applications have been most recently made. Only within a comparatively few years have engineers realized the practical value of these laws outside of the adjustment of errors of observation. The books on Least Squares, which deal with the subject of chance and balanced errors, have been written chiefly from the standpoint of the precision of measurement. This is natural, for the engineering sciences are to a great extent exact sciences, while biology deals with plants and animals which group themselves in various ways, and which possess many varying characteristics. In biology, therefore, the study of variation is all-important. Sanitary engineering is a science which in some ways occupies an intermediate place between the natural sciences and the exact sciences. It deals not only with mathematics and physics, but with chemistry and biology. There are many ways, therefore, in which the laws of frequency may be found useful in sanitation. The purpose of this address is not to formulate these laws in a definite manner, but merely to point out some ways in which they may be used and how a knowledge of the general idea of variation will help to control our use of certain measurements and tests in common use. It is the hope of the author that these studies may stimulate many detailed investigations along similar lines.

The Idea of Variation.—When many different measurements of a certain quantity have been made, it is common to generalize them by computing the average; that is, the numerical mean. This is a simple and useful method, but it often fails to give a complete picture of the individual measurements in the series. In fact, two groups of items of very different magnitude may yield the same average. For example, the average of each of the following series is the same; namely, 7:

	6		1
	7		2
	6		1
	9		3
	7		28
	—		—
Average.....	7	Average.....	7

Although having the same average, the figures in the two groups are very different. Evidently in this case the average does not give a satisfactory generalization.

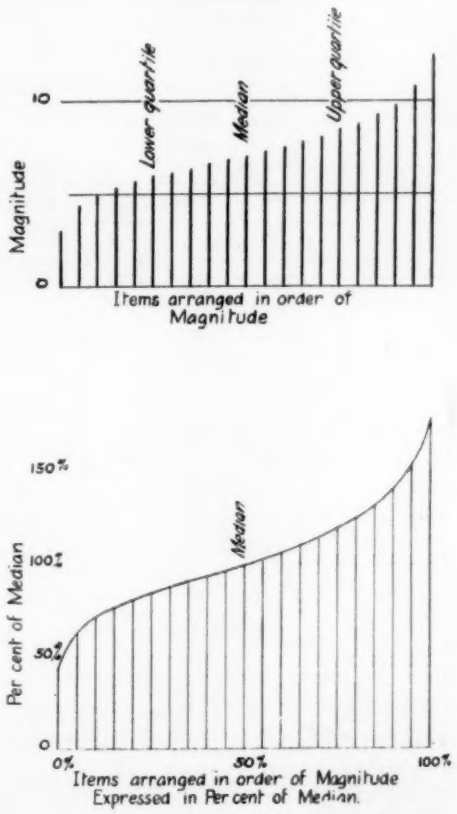
It is possible to study the items of a series in other ways than by computing the arithmetical mean. Let us take the simple case of 21 items, arranged in order of magnitude:

	3.0
	4.4
	5.0
	5.4
	5.7
	6.0
	6.2
	6.4
	6.6
	6.8
	7.0
	7.3
	7.5
	7.8
	8.1
	8.5
	8.8
	9.3
	9.8
	10.8
	12.5
Average.....	7.28

The item that is in the middle of the series when thus arranged is called the median. In this case the median is 7. It is not necessarily the same as the mean, which in this case is 7.28. In the previous comparison of the two dissimilar groups of five items the median of the first group was 7, which was the same as the mean, but the median of the second group was 2, which was much lower than the mean. A comparison of the mean and the median gives a better picture of the groups than either alone. When the items of a series are quite uniform, the mean and the median are nearly alike; but when the mean is much greater than the median, it indicates that the group includes items abnormally high, and when the mean is much less than the median, it indicates that the group includes some items abnormally low. Obviously there is an equal chance of any items being above or below the median, the median being by definition the middle term of the series when the items are arranged in order of magnitude. The labor of arranging a

series of observations in order of magnitude and finding the middle term is not as great as might at first be thought. In case there is an even number of terms, the median may be taken as the average of the middle two terms. This may not be its most probable value when great accuracy is needed, but it is usually near enough for all practical purposes.

FIG. 1.



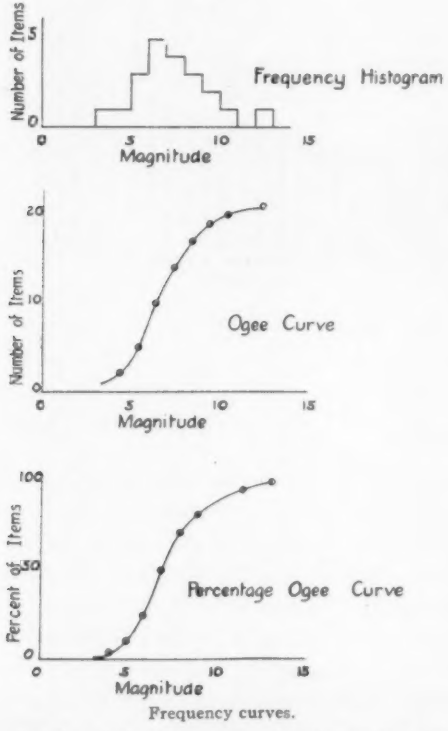
Curve of variation.

The series may be further described by finding values of the terms which lie half way between the median and the ends of the series; that is, one-quarter way from one end of the series to the other. These are called the upper quartile and the lower quartile, and in the series mentioned have the values of 6 and 8.5 respec-

tively. In the same way we might find the value of the term which lies one-tenth of the way from one end of the series, the decentile, and so on. Taken together these are sometimes called the "percentile grades," a term used by Sir Francis Galton.

In Fig. 1 these items are placed in array first in order of magnitude, and second in order of magnitude expressed in terms of percentage of the median. If desired, a horizontal scale may be

FIG. 2.



Frequency curves.

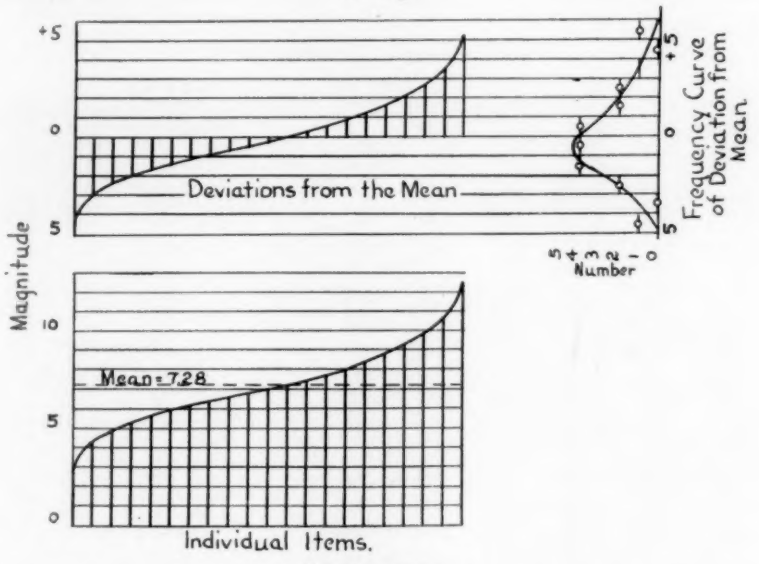
used, the total number of observations being taken as 100 per cent. and the median being, of course, 50 per cent.

Frequency.—Where there is a large number of items in the series the labor of considering them all in array becomes so great that it is easier and better to combine them into groups. When this is done and the results plotted with the magnitudes of the items as abscissæ and the numbers of items in each magnitude group as ordinates, the result is called a frequency curve. This

" frequency polygon " or " frequency histogram " plays a very important part in statistical investigations.

If the numbers in the above-mentioned series are combined into groups and plotted in this way, it will be noticed that there is a certain magnitude which is more common than any other (Fig. 2). Five of the items fall into group 6–7, and the peak of the frequency curve is seen to occur at a magnitude of 6.5. This value is called the *mode*, as it is the one which should be found more often than any other.

FIG. 3.



Frequency curves.

Other methods of showing frequency are illustrated in Fig. 2; namely, the ogee curves. Here the ordinates indicate the number of items which are less in magnitude than the abscissæ.

Dispersion.—Again, we may study our series of items by ascertaining how the individual results vary from the mean value. Plotting them as in Fig. 3, it is seen that the curve is the same as the curve of variation. It will be found that most of the items are relatively close to the mean, but that a few are farther from it, and a still smaller number farther yet. This is shown by the frequency curve of the deviation from the mean. For convenience of discussion these deviations from the mean may be called

"errors." The most probable error is that deviation from the mean which is just as likely to be exceeded as not. It might be termed the "median error." According to Least Squares, the value of the probable error (r) of a set of observations is $0.6745\sqrt{\frac{\Sigma x^2}{n}}$, in which x is any individual error, n the number of observations, and 0.6745 a numerical constant. The expression $\sqrt{\frac{\Sigma x^2}{n}}$ is called the "standard deviation from the mean, or the mean error." In the series given above the mean error is 2.15 and the probable error (r) is 1.45.

Determination of Probable Error.

Item	Deviation from mean x	Square of deviation x^2
3.0	−4.28	18.32
4.4	−2.84	8.07
5.0	−2.28	5.20
5.4	−1.88	3.53
5.7	−1.58	2.50
6.0	−1.28	1.64
6.2	−1.08	1.17
6.4	−0.88	.77
6.6	−0.68	.46
6.8	−0.48	.23
7.0	−0.28	.08
7.3	+0.02	.0004
7.5	+0.22	.05
7.8	+ .52	.27
8.1	+ .82	.67
8.5	+1.22	1.49
8.8	+1.52	2.31
9.3	+2.02	4.08
9.8	+2.52	6.35
10.8	+3.52	12.39
12.5	+5.22	27.25
Mean = 7.28		Sum = 96.83

$96.83 \div 21 = 4.61 = \frac{\Sigma x^2}{n}$.

$\sqrt{4.61} = 2.15$ = standard deviation.

$2.15 \times .6745 = 1.45$ = probable error (r).

$1.45 \div 7.28 = .199$ = coefficient of variation.

Maximum error $= 12.5 - 7.28 = 5.22''$

$5.22 \div 1.45 = 3.5$ = maximum value of $\frac{x}{r}$.

It should be noted that some of the errors are positive and some negative, but that in computing the mean error the sign is disregarded; for all of the values of x^2 are positive. In computing the value of the probable error the frequency curve of deviation is supposed to be symmetrical.

TABLE I.

Probability of the Occurrence of Errors.

r = the probable error = 0.6745m.

m = the mean error = 1.4826r = $\sqrt{\frac{\Sigma x^2}{n}}$.

x = an individual error.

n = number of observations.

$\frac{x}{r}$	0	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0.0000	0.0054	0.0108	0.0161	0.0215	0.0269	0.0323	0.0377	0.0430	0.0484
0.1	0538	0591	0645	0699	0752	0806	0859	0913	0966	1020
0.2	1073	1126	1180	1233	1286	1339	1392	1445	1498	1551
0.3	1603	1656	1709	1761	1814	1866	1918	1971	2023	2075
0.4	2127	2179	2230	2282	2334	2385	2436	2488	2539	2590
0.5	0.2641	0.2691	0.2742	0.2793	0.2843	0.2893	0.2944	0.2994	0.3043	0.3093
0.6	3143	3192	3242	3291	3340	3389	3438	3487	3535	3583
0.7	3632	3680	3728	3775	3823	3870	3918	3965	4012	4059
0.8	4105	4152	4198	4244	4290	4336	4381	4427	4472	4517
0.9	4562	4606	4651	4695	4739	4783	4827	4860	4914	4957
1.0	0.5000	0.5043	0.5085	0.5128	0.5170	0.5212	0.5254	0.5295	0.5337	0.5378
1.1	5419	5460	5500	5540	5581	5620	5660	5700	5739	5778
1.2	5817	5856	5894	5932	5970	6008	6046	6083	6120	6157
1.3	6194	6231	6267	6303	6339	6375	6410	6445	6480	6515
1.4	6550	6584	6618	6652	6686	6719	6753	6786	6818	6851
1.5	0.6883	0.6915	0.6947	0.6979	0.7011	0.7042	0.7073	0.7104	0.7134	0.7165
1.6	7195	7225	7255	7284	7313	7342	7371	7400	7428	7457
1.7	7485	7512	7540	7567	7594	7621	7648	7675	7701	7727
1.8	7753	7778	7804	7829	7854	7879	7904	7928	7952	7976
1.9	8000	8023	8047	8070	8093	8116	8138	8161	8183	8205
2.0	0.8227	0.8248	0.8270	0.8291	0.8312	0.8332	0.8353	0.8373	0.8394	0.8414
2.1	8433	8453	8473	8492	8511	8530	8549	8567	8585	8604
2.2	8622	8639	8657	8674	8692	8709	8726	8742	8759	8775
2.3	8792	8808	8824	8840	8855	8870	8886	8901	8916	8930
2.4	8945	8960	8974	8988	9002	9016	9029	9043	9056	9069
2.5	0.9082	0.9095	0.9108	0.9121	0.9133	0.9146	0.9158	0.9170	0.9182	0.9193
2.6	9205	9217	9228	9239	9250	9261	9272	9283	9293	9304
2.7	9314	9324	9334	9344	9354	9364	9373	9383	9392	9401
2.8	9410	9419	9428	9437	9446	9454	9463	9471	9479	9487
2.9	9495	9503	9511	9519	9526	9534	9541	9548	9556	9563
3.0	0.9570	0.9577	0.9583	0.9590	0.9597	0.9603	0.9610	0.9616	0.9622	0.9629
3.1	9635	9641	9647	9652	9658	9664	9669	9675	9680	9686
3.2	9691	9696	9701	9706	9711	9716	9721	9726	9731	9735
3.3	9740	9744	9749	9753	9757	9761	9766	9770	9774	9778
3.4	9782	9786	9789	9793	9797	9800	9804	9807	9811	9814
3	0.9570	0.9635	0.9691	0.9740	0.9782	0.9818	0.9848	0.9874	0.9896	0.9915
4	9930	9943	9954	9963	9970	9976	9981	9985	9988	9990
5	9993	9994	9996	9997	9997	9998	9998	9999	9999	9999
0	1.0000									

Without going into detail, it may be said that it is possible to compute the frequency with which errors of a given magnitude are found. By definition the probable error is just as likely as not to occur. Its chance of occurring is 1 : 1; that is, 1 in 2. This

probability is generally stated as ½, or 0.50, or 50 per cent. The chance of any deviation being less than certain amounts is shown in Table I, taken from Merriman's book on Least Squares. In the first column of this table the fraction $\frac{x}{r}$ represents the magnitude of an individual deviation from the mean compared to the probable error. For example, if $\frac{x}{r} = 1$, the deviation from the mean is the same as the probable error; and the chances are even that x will occur. The probability is therefore stated as 50 per cent., or 0.500, as given in the second column. The probability that a deviation of less than one-half of the probable error will occur is 0.2641, and that an error less than twice the probable error will occur is 0.8227. The sum of the chances that a deviation will or will not occur is, of course, unity. Probabilities of the occurrence of errors less than other relative magnitudes, as compared with the most probable error, can be picked out from the various columns of this table. Probabilities of the occurrence of "greater errors" can be obtained by subtracting the figures in the table from 1.

The values of $\frac{x}{r}$ for different probabilities, according to Merriman and Jones, are given in Table II.

In Jones's Tables, page 160, will be found another probability table. Unlike Merriman's, this is based on half, not on all of the variation curve, and the figures for probability indicate the probability that the given value of $\frac{x}{r}$ will be exceeded.

Thus, Merriman's probability value of 0.80 indicates that 80 per cent. of all the observations will be less than $\frac{x}{r} = 1.90$. Therefore $1 - 0.80$, or 0.20, of the observations will be greater than 1.90. Of these, 0.10 will be at one end of the curve and 0.10 at the other end. Hence we find 1.90 opposite 0.10 in Jones's table.

Probability Paper.—The values of the probability of the occurrence of the different values of $\frac{x}{r}$ (based on Jones's figures for half the frequency curve) are shown in Fig. 4. This is a graphical representation of the law of error, on one side of the median. For obvious reasons it is not convenient to use.

TABLE II.

Probabilities of the Occurrence of Certain Values of $\frac{x}{r}$

A	B	C
Ratio of given error (x) to the probable error (r) $\left(\frac{x}{r}\right)$.	Probability of the deviation being less than this value (including all observations regardless of sign).	Probability of the deviation being greater than this value (including only half of the observation, *i.e.*, of the same sign).
.02	.01	.495
.04	.02	.490
.06	.03	.485
.09	.05	.475
.19	.10	.450
.38	.20	.400
.58	.30	.350
.77	.40	.300
1.00	.50	.250
1.25	.60	.200
1.54	.70	.150
1.90	.80	.100
2.438	.90	.050
3.045	.96	.020
3.449	.98	.010
3.821	.99	.005
4.267	.996	.002
4.587	.998	.001
4.887	.999	.0005
5.250	.9996	.0002
5.525	.9998	.0001
5.783	.9999	.00005
6.090	.99996	.00002
6.332	.99998	.00001
6.592	.99999	.000005
6.853	.999996	.000002
7.063	.999998	.000001
7.258	.999999	.0000005
7.548	.9999996	.0000002
7.758	.9999998	.0000001
7.967	.9999999	.00000005

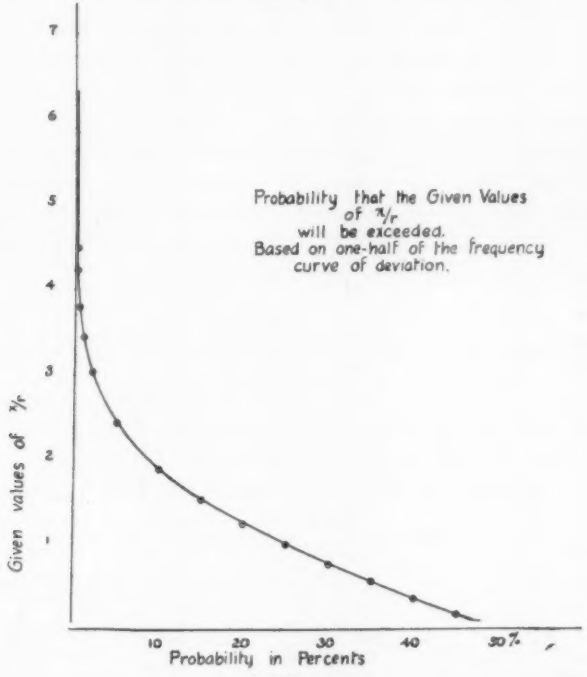
B. From Merriman's "Least Squares," page 221.
C. From Jones's Tables, page 160.

It occurred to my partner, Allen Hazen, in 1914, that a paper might be ruled with the horizontal scale so divided that this curve of probability would plot as a straight line. And hence any series of observations which varied in accordance with this probability

would also plot as a straight line, for the same reason that the curve of deviation and the curve of variation are coincident. This paper was first used in a study of the storage to be provided in impounding reservoirs for municipal water supplies.[2]

In making this paper, the central point on the horizontal scale was marked 50 and represents the median observation; that is, the item which has a probability of 0.50. The other points on the scale are laid off in either direction from this central point, so that

FIG. 4.



Probability curve.

40 and 60, 30 and 70, 1 and 99, 0.01 and 99.99, etc., are equidistant from the centre. In other words, the frequency curve is assumed to be symmetrical.

The distances from the centre are laid out by plotting the values of $\frac{x}{r}$ for corresponding values of probability as given in Jones's table. Thus 0.01 is 5.525 divisions on the scale from the centre,

[2] Allen Hazen, *Trans. Am. Soc. C. E.*, lxxvii, p. 1539.

0.1 is 4.587 divisions from the centre, etc., as shown on the attached sheet.

The figures used by Hazen in laying out the diagram were substantially those given above. Hazen gives them as shown in Table III.

TABLE III.

Relative Distances of Lines on Probability Paper from Central or 50 Per Cent. Line.

(This covers one-half of sheet. The other half is reversed.)

Line, Per cent.	Relative distance	Line, Per cent.	Relative distance
50	0.000	8	2.083
48	0.074	7	2.188
46	0.149	6	2.305
44	0.224	5	2.439
42	0.300	4	2.596
40	0.376	3	2.789
38	0.453	2	3.045
36	0.531	1	3.450
34	0.611	0.9	3.507
32	0.693	0.8	3.573
30	0.777	0.7	3.646
28	0.864	0.6	3.727
26	0.954	0.5	3.821
24	1.047	0.4	3.933
22	1.145	0.3	4.077
20	1.248	0.2	4.267
19	1.302	0.1	4.585
18	1.357	0.09	4.630
17	1.415	0.08	4.685
16	1.474	0.07	4.748
15	1.537	0.06	4.817
14	1.602	0.05	4.900
13	1.670	0.04	5.000
12	1.742	0.03	5.120
11	1.818	0.02	5.290
10	1.900	0.01	5.550
9	1.988	0	

With the diagram thus laid out, the values of $\frac{x}{r}$ plotted on the probability scale will fall on a straight line. And, conversely, if the items of a series of observations plotted on this paper fall on a straight line, it indicates that they form a probability series; that is, they occur according to the laws of chance.

Hazen's paper is intended for symmetrical frequency curves; but not all frequency curves are symmetrical. Such writers as Karl Pearson and his school of biometricians have described various types of frequency curves. These have not been included in the present study, but there seems to be no reason why they, too, may not be simplified and made more useful by methods similar to Hazen's.

In any series of observations some items are liable to be so far from the mean as to be of doubtful value. These should be rejected. Merriman has given the values of the observations which should be rejected in any series as follows. Naturally the ratio of $\frac{x}{r}$ increases according to the number of observations in the series:

Number of observations in the series	$\frac{x}{r}$	Number of observations in the series	$\frac{x}{r}$
3	2.05	18	3.26
4	2.27	19	3.29
5	2.44	20	3.32
6	2.57	21	3.35
7	2.67	22	3.38
8	2.76	23	3.41
9	2.84	24	3.43
10	2.91	25	3.45
11	2.96	30	3.55
12	3.02	40	3.70
13	3.07	50	3.82
14	3.12	75	4.02
15	3.16	100	4.16
16	3.19	200	4.48
17	3.22	500	4.90

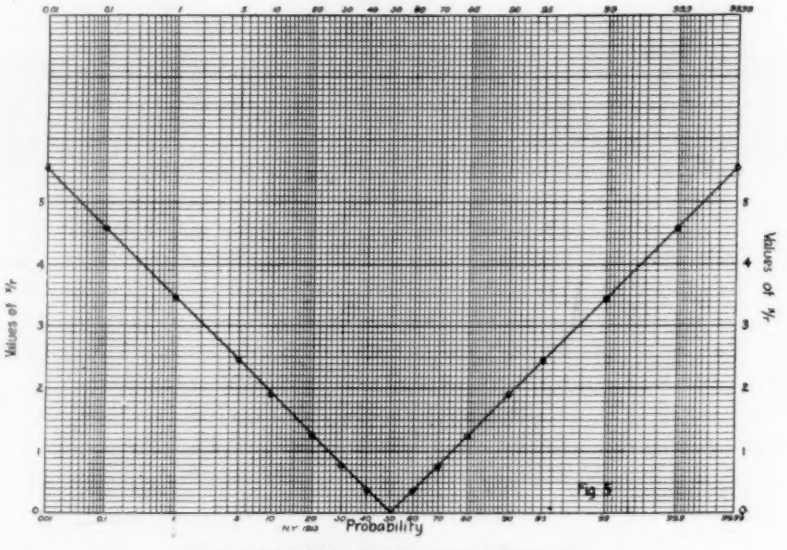
In the series of 21 items given above, the last item has a value of 12.5. The value of $\frac{x}{r}$ is 3.5. According to Merriman, this item should be excluded from the series.

If, in a series of daily observations of the number of bacteria in a filter effluent extending over a year the deviation of any determination from the mean should be found to be more than five times as much as the probable error, to use a round number, this should be rejected from the series as being, for some reason or other, abnormal. This principle is likely to play an important part in future discussions of this subject.

Use of Arithmetic-probability Paper.—On arithmetic-probability paper the normal curve of error plots out as a straight line on either side of the median point. This follows from construction, but it is illustrated by Fig. 5, in which the ordinates represent values of $\frac{x}{r}$ and the abscissæ probability expressed in percentage.

It is interesting to notice also that the coefficients of the different terms of a binomial series of the form $(1+1)^n$ plot out on this paper as a straight line. This also follows directly from

FIG. 5.



Law of probability plotted on probability paper.

the laws of chance. A discussion of this relation may be found in works on the theory of statistics (Fig. 6).

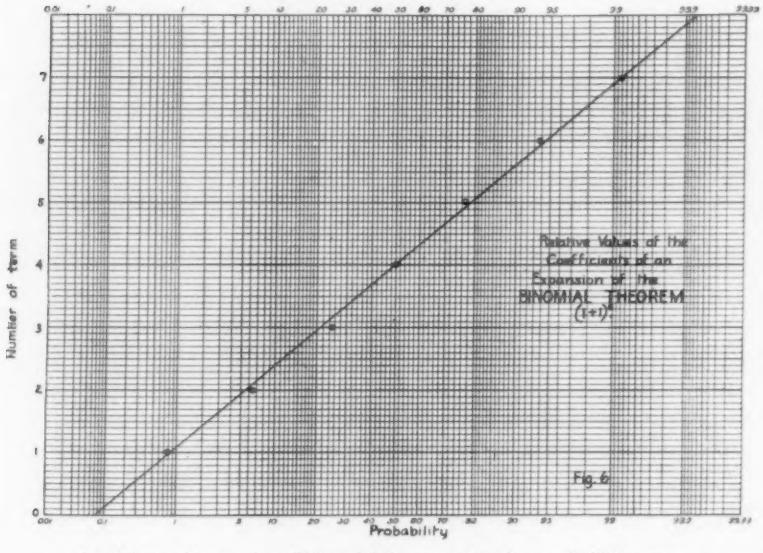
Fig. 7 shows the results obtained in chance by tossing 14 coins 150 times according to the table in Elderton's "Primer of Statistics." In this case the ordinates represent the number of heads which appeared. It will be noticed that the median was about 7. If there had been an indefinite number of throws, instead of 150 throws, the median would, of course, have been exactly 7; that is, heads would have been thrown half of the time. The probability line shows that 9 heads would be thrown once in every ten times,

11 heads once in every 100 times, while once in 10,000 times all the coins would be thrown as heads.

King, in his "Elements of Statistical Method," page 103, gives similar results obtained by throwing three dice 196 times.

Merriman, on page 172 of his "Least Squares," gives as an example of frequency the results of measurements of the height of 18,780 soldiers. These results plotted on probability paper are shown in Fig. 9. It will be noticed that the points fall almost exactly on a straight line. This line shows the median height

FIG. 6.



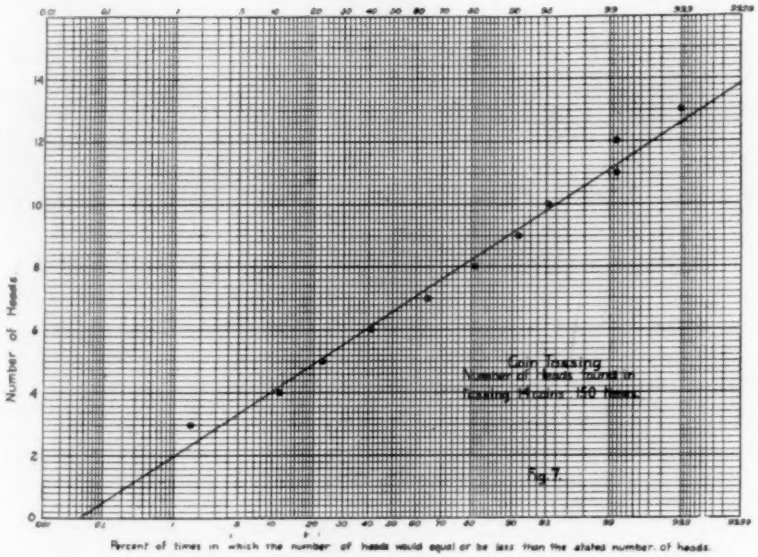
Coefficients of expansion of binomial theorem plotted on probability paper.

to be 5 feet 7 inches. One soldier in ten had a height of 5 feet 3½ inches, one in every hundred a height of 5 feet 1 inch, and it may be inferred, from the extension of the line, that one soldier in every 10,000 would have a height of only 4 feet 9½ inches. On the other hand, one soldier in every ten had a height of 5 feet 10½ inches; one in every 100 had a height of 6 feet 1 inch, and one in every 10,000, 6 feet 4½ inches. Again, the probability line shows that a height of 6 feet or more was found 2.6 per cent. of the number of times; that is, one soldier in 38 was 6 feet or more in height.

Fig. 10 shows the ages of scholars in a certain grade in the schools of St. Louis. It will be seen that the ages varied from 11 to 18, the median age being 13.8. The various points fell nearly on a straight line. The probability line shows that half of the scholars in this grade were between the ages of 13 and 14.6 years, while 90 per cent. of them were between the ages of 11.8 and 15.8.

In Fig. 11 the annual rainfalls at Boston, Mass., have been plotted for a period of 91 years, the figures being taken from the

FIG. 7.


Number of Heads
Coin Tossing
Fig 7.
Percent of times in which the number of heads would equal or be less than the stated number of heads.

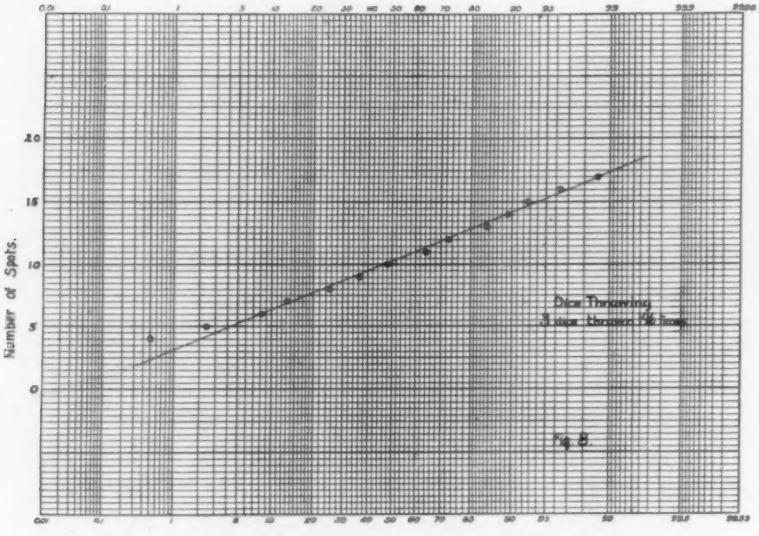
Results of coin tossing plotted on probability paper.

records of the United States Weather Bureau. They show that the median rainfall during this period was 44.5 inches. In one year in every ten the rainfall was less than 34 inches, and in one year in every ten it was greater than 54.5 inches. From the probability line an annual rainfall as low as 20 inches might be expected once in every 1000 years, and a rainfall of 75 inches or more might be expected once in every 10,000 years.

In Fig. 12 will be found similar rainfall records for Philadelphia. This series also covers a period of 91 years, and the points fall nearly on a straight line, except in the case of a few of the

wettest years. At Philadelphia the median rainfall was found to be 42 inches. In 10 per cent. of the years the rainfall was less than 33.5 inches, in 10 per cent. of the years it was greater than 51 inches. From the probability line it may be inferred that a rainfall as low as 17 inches or as high as 67 inches may occur once in 10,000 years. This method of study gives no idea as to when these high or low rainfalls may occur.

FIG. 8.



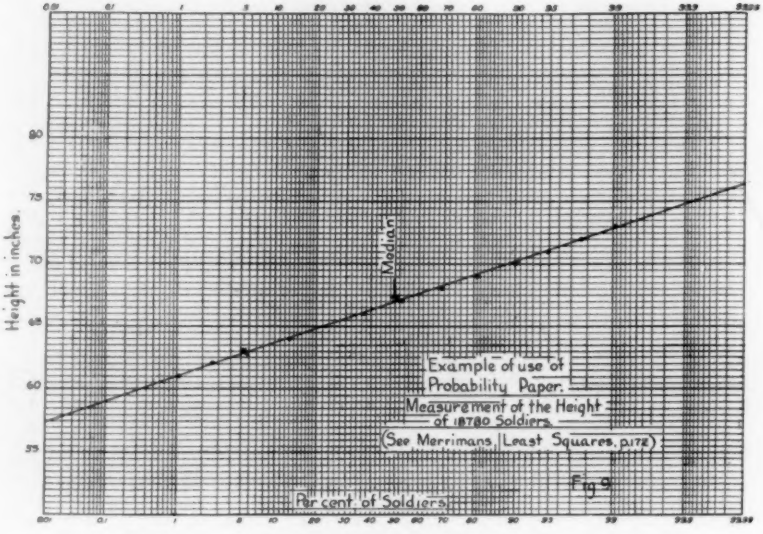
Results of dice throwing plotted on probability paper.

Fig. 13 shows the use of probability paper as applied to stream flow by Allen Hazen.[3]

Death-rates of Cities and Towns.—It has been found that if the death-rates of the cities of Massachusetts for any given year or for a term of years are plotted on arithmetic-probability paper, the results fall nearly in a straight line. This is shown by Fig. 14 for the year 1910. During this year the median death-rate for Massachusetts cities was 15.6 per 1000, and on the basis of the probability line one city in every ten had a death-rate higher than 19.5, while one city in every ten had a death-rate less than 11.7. A line of

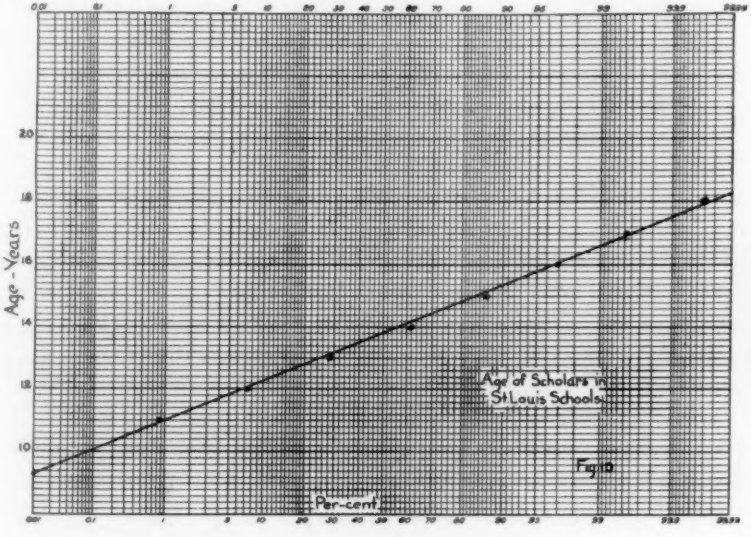
[3] *Loc. cit.*

FIG. 9.



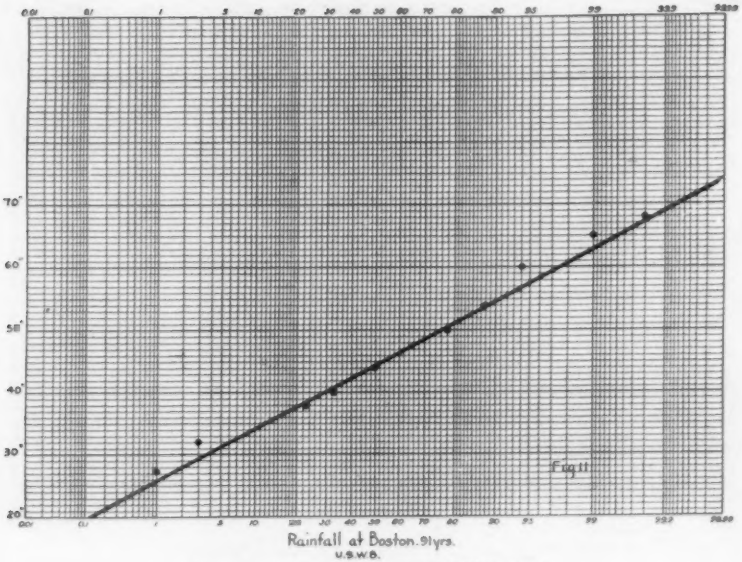
Measurement of height of soldiers plotted on probability paper.

FIG. 10.



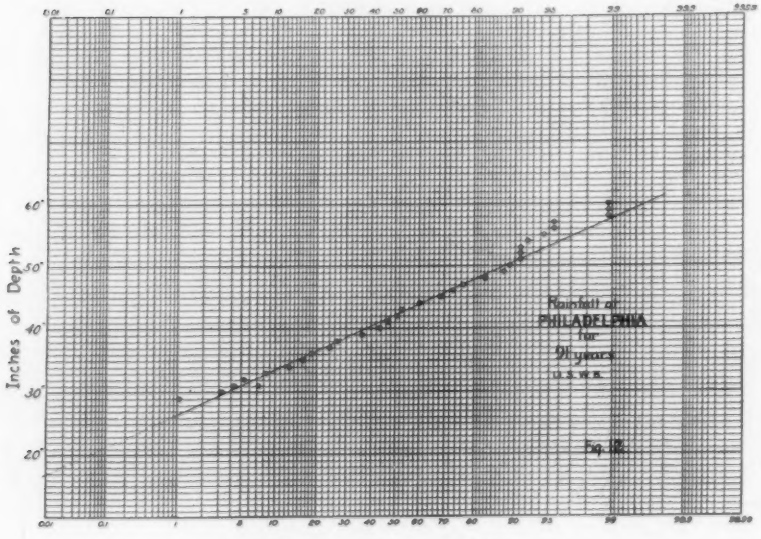
Age of scholars plotted on probability paper.

FIG. 11.



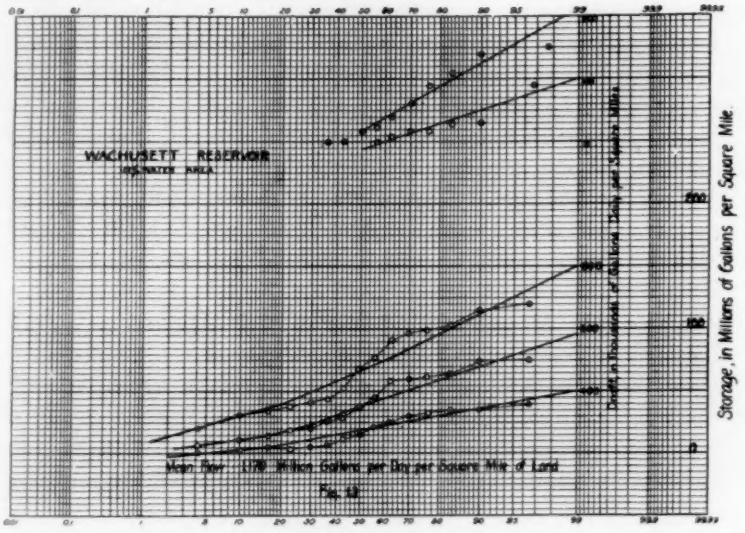
Annual rainfall plotted on probability paper.

FIG. 12.



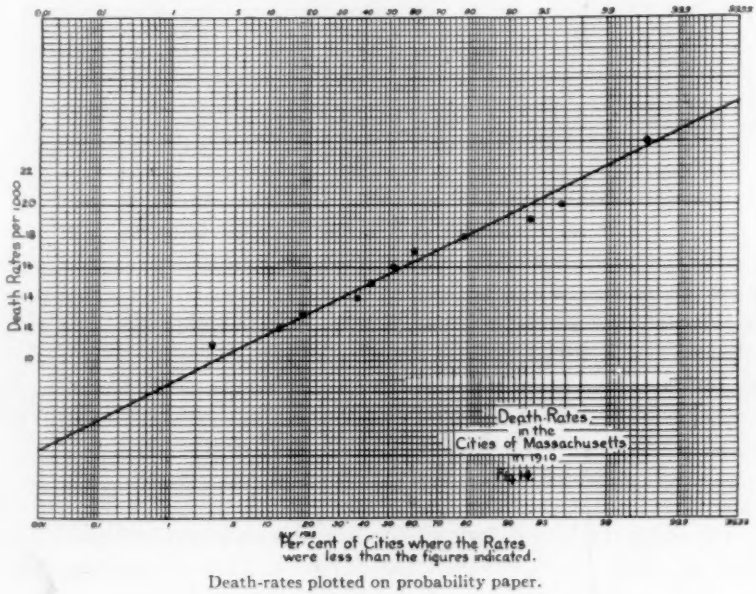
Annual rainfall plotted on probability paper.

FIG. 13.



Stream flows plotted on probability paper.

FIG. 14.

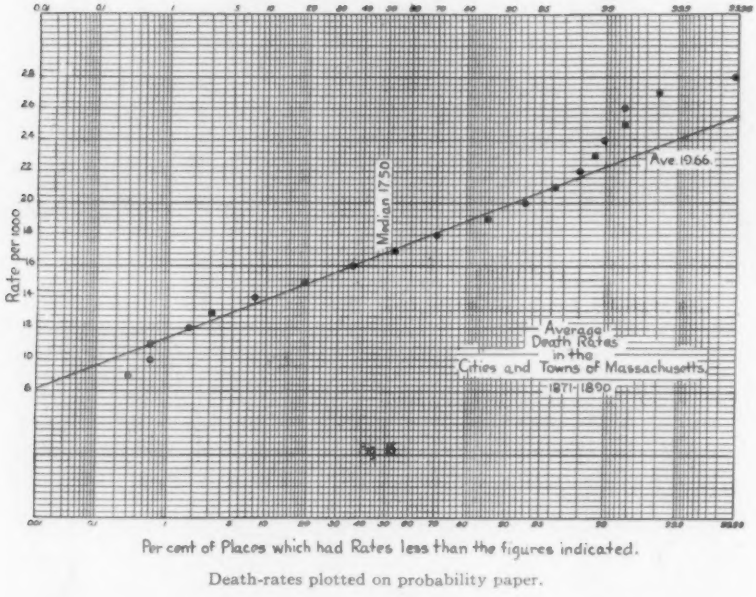

Death Rates per 1000
Death-Rates in the Cities of Massachusetts in 1910
Per cent of Cities where the Rates were less than the figures indicated.

Death-rates plotted on probability paper.

this sort gives a better indication of the prevailing death-rates in the state than any mere average of the results could possibly do.

Fig. 15 shows a similar probability line for the average death-rates in the cities and towns of Massachusetts for the period from 1871 to 1890. During this period the average of the death-rates was 19.66, but the median was only 17 per 1000. It is evident that during that period abnormally high death-rates in a few places influenced the average. During this period 90 per cent. of the death-rates of the cities were between 13 and 23 per 1000. Again,

FIG. 15.


Rate per 1000
Median 17.50
Ave. 19.66
Average Death Rates in the Cities and Towns of Massachusetts 1871-1890
Per cent of Places which had Rates less than the figures indicated.

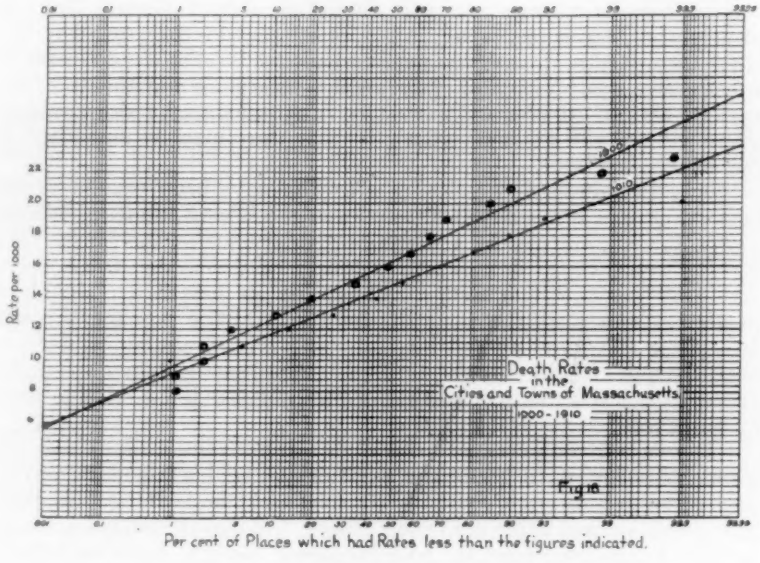
Death-rates plotted on probability paper.

in Fig. 16 we see that during the year 1900 the average death-rate for cities and towns was 18.26, the median 16.4, and 90 per cent. of the death-rates were between 11.6 and 21. But in 1910 the average death-rate had fallen to 16.04 and the median to 14.8, while 90 per cent. of the death-rates lay between 10.8 and 18.4. The lower position on the sheet of the line for the year 1910 indicates that in that year the death-rates were generally lower during 1910, while the latter slope of the line shows a greater uniformity than in 1900. It is evident that during the ten years from 1900

to 1910 the cities and towns which previously had high death-rates reduced their rates more rapidly than those in which the death-rates had previously been lower. In Fig. 17 some of the data previously mentioned are expressed in terms of percentages of the mean, and it is evident that in any year one city in every ten is likely to have a death-rate nearly 25 per cent. greater or less than the median.

Fig. 18 shows the probability lines for the death-rates of the

FIG. 16.


Rate per 1000
1900
1910
Death Rates in the Cities and Towns of Massachusetts, 1900-1910
Fig 18
Per cent of Places which had Rates less than the figures indicated.

Death-rates plotted on probability paper.

entire state of Massachusetts for three periods, 1860–70, 1880–90, and 1900–12. It will be noticed that the rates have been becoming more uniform in recent years. In the first period there was a probable variation of the death-rate in any year from the 11-year median of 10 per cent. one year in every decade; in the second period this was only 3.5 per cent., and in the third period only 2.5 per cent. The medians were respectively 23.61, 24.02, and 18.60 per 1000.

(To be continued)

Breech Mechanisms for Guns. ANON. (*The Times* (London) *Engineering Supplement*, No. 498, April 28, 1916.)—Rapidity of gun-fire depends chiefly upon the speed with which the breech block or plug is removed and replaced as often as a shell is inserted and fired. Since the pressure which the block has to resist is very high, amounting to from 14 to 17 tons per square inch of its surface, the fitting must be close and secure, and the material used must be of high grade. The wear and tear of the parts of the mechanism, which will often total a hundred separate pieces, is very severe in all quick-firing guns, and has to be provided for by the strictest attention to material and workmanship. In most modern guns the breech fitting consists of a screw, for it is almost the only fastening that can satisfy the requirements of ample resistance to the pressure employed, coupled with easy removal and adapted to the employment of an effective gas check and convenient priming arrangements. The various actions of operation must be accomplished by single movements of a lever or hand-wheel, so that they may be embodied in the mechanism itself.

Only two methods of closing a breech have been practised, one consisting of a screw inserted axially in the breech, and the other a wedge thrust in a slot in a direction transversal to the bore. The Krupp breech block is a notable example of the wedge form. The action is simple. The wedge includes on its length a plain blank portion which seals the bore of the gun and the passage through which the charge is passed into it. The Krupp sliding wedge has been sharply criticised by the artillerists of countries which adopt the screw breech, on the ground that it does not provide a reliable form of gas check.

The serious objections to the wedge system induced British and French artillerists to adopt the axial design of breech block having an interrupted screw, a swinging console, and the de Bauge design of gas check, named after a French officer, Colonel de Bauge, who remodelled and improved it. Actual screw designs have undergone but slight variations, chiefly in the number of interruptions and in the longitudinal sections. Operating mechanisms have been and are extremely varied, but, while they possess apparently many complications, they are most simple and rapid in action.

NOTE ON THE APPLICABILITY OF THE PAPER PULP FILTER TO THE SEPARATION OF SOLIDS FROM LIQUIDS.*

BY

S. L. JODIDI, Ph.D.,

Office of Plant Physiological and Fermentation Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

INTRODUCTION.

Of the materials used in analytical work for the separation of liquids from precipitates, filter-paper and asbestos are the best known, while filters of cloth, wool, cotton, silk, etc., are ordinarily employed in work other than analytical. Whereas, paper pulp may have been used in a few cases for special purposes, it is noteworthy that the pulp filter, which has been shown by E. H. Kellogg and the writer to be generally applicable to quantitative [1] analysis, is—so far as we are aware—not even mentioned in voluminous text-books of analytical chemistry, such as Fresenius,[2] Treadwell,[3] Hoppe-Seyler,[4] and others. Even in Abderhalden's up-to-date "Handbuch der biochemischen Arbeitsmethoden," made up of not less than ten volumes with a total of about eight thousand pages, the paper pulp [5] is mentioned in but three sentences. In the Handbuch, however, the pulp is not as such recommended for the filtration of fine precipitates, like barium sulphate, but *in connection with paper filters.*

IMPORTANCE OF A GOOD FILTER FOR ANALYTICAL WORK.

The analytical chemistry is largely based upon estimation of precipitates. While volumetric, acidimetric, and, especially, colori-

* Published by permission of the Secretary of Agriculture and communicated by the Author.

[1] Jodidi, S. L., and Kellogg, E. H., *Jour. Ind. and Engin. Chem.*, **8**, 317, 1916.

[2] Fresenius, "Quantitative Analysis," vol. I, p. 88, 1903.

[3] Treadwell, "Analytical Chemistry," vol. ii, p. 16, 1907.

[4] Hoppe-Seyler's "Handbuch der Physiol.-Pathol. Chem. Anal.," p. 5, 1909.

[5] "Handbuch der biochemischen Arbeitsmethoden," by Emil Abderhalden, vol. I, 98.

metric and nephelometric [6] methods are coming more and more into use, the quantitative and qualitative analysis is still, in most cases, dependent upon the determination of precipitates. Of all operations necessary to quantitatively obtain the precipitates in a pure form, their filtration through filter-paper is one which is not only very tedious and time-consuming, but requires also certain skill. That filtration (including decantation) takes a considerable part of the time necessary for an analysis every chemist knows from his own experience, and is also evident from the fact that the text-books of analytical chemistry usually devote much space and painstaking details to the processes of decantation, filtration, and washing of precipitates. It is, therefore, quite advantageous to make use of the pulp filter, which, in connection with a research into the chestnut [7] bark disease, was shown to be applicable to the estimation of phosphorus,[8] calcium,[9] and magnesium,[9] and to quantitative [10] analysis in general. The pulp filter permits of comparatively rapid filtration and washing, so that one is able to save considerable time and labor. A simple consideration will show why this filter permits of rapid work, combined with economy and accuracy.

RAPIDITY.

The actual filtration through an ordinary paper-filter, because it snugly rests on the walls of the funnel, takes place chiefly through a very small portion only; namely, through its conical part, which freely hangs over the stem of the funnel. As the filtration goes on, this free filtering part is gradually plugged up, which more and more retards the filtration. On the other side, the filtration on the pulp filter, whether used with a Gooch crucible or with a perforated plate, takes place through a number of holes (usually from 60 to 70), so that when some of them are plugged up during filtration the others still continue to filter well. But what seems to be of greater importance is the fact that the

[6] Kober, P. A., and Egerer, G., *Jour. Amer. Chem. Soc.*, **37**, 2373, 1915; Kober, P. A., and Graves, E. E., *Jour. Ind. and Engin. Chem.*, **7**, 843, 1915; S. S. Graves and P. A. Kober, *Jour. Amer. Chem. Soc.*, **37**, 2430, 1915.

[7] S. L. Jodidi, *Jour. Amer. Chem. Soc.*, **37**, 1708, 1915; S. L. Jodidi and E. H. Kellogg, JOUR. FRANKLIN INSTITUTE, **180**, 349, 1915.

[8] S. L. Jodidi and E. H. Kellogg, *Biochemical Bulletin*, **5**, 87, 1916.

[9] S. L. Jodidi and E. H. Kellogg, JOUR. FRANKLIN INSTITUTE, **181**, 217, 1916; *Chemical Engineer*, **23**, 60, 1916.

[10] S. L. Jodidi and E. H. Kellogg, *Jour. Ind. and Engin. Chem.*, **8**, 317, 1916.

work with the paper pulp filter enables one to make use of suction, which, as in the case of the asbestos filter, considerably accelerates the rapidity of the filtration.

The direct experiment shows (which seems also evident) that, *cæteris paribus*, the thicker a pulp filter is, the more slowly it filters, and *vice versa*. By using, however, pulp emulsion of equal consistency—from 1.5 to 2 c.c.[11] of water for each centigramme of filter-paper—and by preparing the pulp filters in a definite way it is fairly easy to obtain filters of uniform thickness and efficiency.

To illustrate the rapidity of filtration through a pulp filter, as compared with an ordinary paper filter, it seems worth while here to arrange a few previous data in tabular form.

TABLE I.

Precipitate	Decantation, filtration, and washing of precipitate requires:		Remarks
	On paper filter, minutes	On pulp filter, minutes	
Ammonium phosphomolybdate [12]	20–35	5	The paper filter used was an S. & S. folded filter, No. 588, of 12½ cm. diameter.
Calcium oxalate [13]	30–35	5	
Magnesium ammonium phosphate [14]	30	3–6	The paper filter employed was an S. & S. filter, No. 590, of 9 cm. diameter.
Barium sulphate [15]	35	10	The same paper filter was used as in the case of magnesium ammonium phosphate.
Silver chloride	30–40	8–15	The same paper filter was used as in the case of magnesium ammonium phosphate.
Potassium platinic chloride	40–50	15	The same paper filter was used as in the case of magnesium ammonium phosphate.

[11] S. & S. filters, Nos. 589 and 588, of 12½ cm. diameter, weigh about 0.95 and 0.8 gr. respectively. Equally, an S. & S. filter, No. 595, of 11 cm. diameter, weighs about 0.6 gr. The weight of an 11-cm. filter of common sheet filter-paper was found to be 0.75 gr. The average weight of one filter of the above descriptions—frequently used for analytical work—is about 0.75 gr., which, reduced with some 150 c.c. of water (2 c.c. water to 1 centigramme paper), gives a paper pulp which is ordinarily suitable for analytical and other purposes.

[12] Not published yet.

[13] JOUR. FRANKLIN INSTITUTE, **181**, 222, 1916.

[14] *Ibid.*, **181**, 229, 1916.

[15] *Jour. Ind. and Eng. Chem.*, **8**, 318, 1916.

ACCURACY.

For analytical purposes the accuracy of an ordinary paper filter, though half of it is threefold, is the accuracy of which just one filter layer is capable, because the other half of an ordinary filter is but single-folded. The pulp filter, on the other hand, has a manifold filtering surface, as can be seen from the following consideration. An 11-cm. filter, *e.g.* (frequently used in quantitative analysis), has a total filtering surface of 95 sq. cm., whereas a Gooch crucible (with a bottom of 2.22 cm. in diameter) has 3.87 sq. cm. of filtering surface. Hence, by using the reduced pulp of an 11-cm. filter for five Gooches, the filtering surface of the pulp filter can be made up of four or five layers. While this is not uniformly the case throughout the filter, its weakest part may safely be assumed to have not less than two or three layers. For this very reason the filtrates from pulp filters are, as a rule, much clearer than those from paper filters and comparatively seldom need refiltration.

ECONOMY.

The above calculation shows that the pulp of a filter of 11-cm. diameter is sufficient for four or five Gooches, *i.e.*, for four or five quantitative analyses, which stands in agreement with the

TABLE II.

Paper filters used	Diameter of filter, cm.	Economy of filter-paper obtained by reducing the paper filters to pulp, per cent.	Diameter of filter, cm.	Economy of filter-paper obtained by reducing the paper filters to pulp, per cent.	Diameter of filter, cm.	Economy of filter-paper obtained by reducing the paper filters to pulp, per cent.
S. & S., No. 588, folded [16]	9	166	11	248	12½	320
S. & S., No. 595[17]	9	201	11	300	12½	387
S. & S., No. 589...	9	190	11	284	12½	367
S. & S., No. 598...	9	300	11	448	12½	579
Commonest sheet filter-paper	9	313	11	467	12½	603
Average.....	..	234	..	349	....	451

[16] The details will be published in *Biochemical Bulletin*, **5**, 87–94. 1916.

[17] JOUR. FRANKLIN INSTITUTE, **181**, 231, 1916.

direct experiment. This fact will readily be comprehended when we consider that at most half of an ordinary paper filter can for analytical purposes be utilized, since half of it is threefold. As the filter, however, is never filled to its upper edge, it is fair to state that from two-thirds to three-quarters of the ordinary paper filter is wasted, whereas the filtering surface of the pulp filter is fully utilized.

For the sake of convenience the results in question recalculated to filters of 9, 11, and 12½ cm. diameter, respectively, are presented in Table II.

Table II shows that when paper filters of 9, 11, and 12½ cm. diameter, respectively, are reduced with water to pulp, there results an average economy of filter-paper amounting to 234, 349, and 451, respectively, the total average being 345 per cent. This is the arithmetical expression of the experimentally-demonstrated fact that one quantitative paper filter of average thickness and size, when reduced with water to pulp, yields enough of it to cover about four Gooch crucibles with pulp filters.

THE PAPER PULP FILTER AS COMPARED WITH OTHER FILTERS GENERALLY EMPLOYED IN QUANTITATIVE ANALYSIS.

So far as quantitative analysis is concerned, good filter-paper was preferably used for the separation of precipitates from liquids. It is perfectly true that the Gooch [18] asbestos filter is extensively used in analytical work, since it offers several advantages, chief among which is the rapidity and accuracy of work, as well as the possibility of using the same asbestos filter for several consecutive determinations. But it is true, also, that, in addition to the asbestos filter, the ordinary paper filter is still employed to a great extent in analytical, synthetical, and other work. Yet it is a matter of common knowledge that paper filters, far from being a quick filtering medium, yield not infrequently turbid filtrates or even break during filtration, which necessitates repeated refiltrations. On the other hand, the pulp filter, which never breaks and permits of uniform and comparatively rapid work, gives, as a rule, clear filtrates. For these and other reasons outlined above, the paper filter should be replaced by the pulp filter, wherever pos-

[18] *Jour. Amer. Chem. Soc.*, **12**, 45 (1883); *Ber. Deutsch. Chem. Ges.*, **32**, 2142 (1899). See also Munroe crucible, *Jour. Analyt. Chem.*, **2**, 241 (1888); *Chem. News*, **58**, 101 (1888).

sible, since the latter offers many advantages. It retains [19] fine precipitates, such as ammonium phosphomolybdate, calcium oxalate, etc., more readily than a paper filter or a new asbestos filter. It is more accessible, easier to handle, and requires less time and skill for its preparation than the asbestos filter. The work with the pulp filter is more convenient and more rapid than with the paper filter. The fact that the use of the pulp filter enables one to make considerable saving of filter-paper is at present especially significant in view of the scarcity of good filter-paper in this country.

WHEN IS THE PAPER PULP FILTER APPLICABLE?

We had already occasion to indicate as to why the pulp filter is preferable to either the paper filter or asbestos filter. As to the applicability of the pulp filter, it may generally be stated that it is applicable wherever the ordinary paper filter can be used. Thus it was demonstrated in previous papers [20] that the pulp filter can be used for the quantitative estimation of the acids—phosphoric, hydrochloric, sulphuric; and of the bases—potassium, ammonium, barium, calcium, magnesium, silver; and for quantitative analysis in general. It is a matter of course that it can be applied also to qualitative analysis, to preparation work, or wherever crystallized or more or less crystalline precipitates have to be separated from neutral or moderately acid and alkaline liquids. The paper pulp filter, however, should not be used for the filtration of strongly acid or alkaline liquids (which holds also true for the ordinary paper filter), in which case filters of asbestos or glass wool are preferable; nor should the pulp filter be used for separation of colloidal substances.

For the filtration of very small precipitates—from a few milligrammes down to one milligramme or less—contained in a small volume of liquid, the common paper filter of small size may in some cases be preferred. Especially will this be the case whenever it is essential to have the substance absolutely free from paper fibre

[19] That precipitates like calcium oxalate, barium sulphate, and ammonium phosphomolybdate frequently pass through filter-paper is so well known a fact that we here need not dwell upon it. See, in this connection, S. L. Jodidi and E. H. Kellogg, JOUR. FRANKLIN INSTITUTE, **181**, 228, 1916, footnote; *Biochem. Bulletin*, 5, 87–94, 1916.

[20] *Loc. cit.*

On the other hand, the pulp filter will render very good services for the refiltration of considerable quantities of not quite clear liquids, or for the separation of comparatively large quantities of liquids from small precipitates.

It may be emphasized here that whether a single analysis or series of them are to be made, the pulp filter offers distinct advantages, because it enables one to accomplish the work in less time with less filtering material and with just as accurate results as can be obtained with good paper filters.

CONCLUSIONS.

1. The reasons are outlined in detail as to why the pulp filter (whenever applicable) is superior to the paper filter and asbestos filter—the economy of filter-paper, rapidity and accuracy of work, and easy accessibility being the most important factors involved in the use of the pulp filter.

2. The instances are definitely stated as to when the pulp filter is applicable, or is to be used in preference to either the paper filter or asbestos filter.

Bureau of Plant Industry, U. S. Department of Agriculture,
WASHINGTON, D. C., April, 1916.

The Unit of Viscosity Measurement. P. C. MCILHINEY. (*The Journal of Industrial and Engineering Chemistry*, vol. 8, No. 3, May, 1916.)—The scientific world expresses the results of measurements of viscosity in terms of absolute viscosity, of which the units are directly related to the fundamental units of mass, length, and time. The practical world speaks of Saybolt seconds, Engler numbers, etc. The absolute C. G. S. unit of viscosity is a relatively large one, so that water and similar liquids have absolute viscosities that are inconveniently small numbers, and, furthermore, without giving it a name, it is impracticable to use such a unit in commercial testing. The study of this important physical property of liquids has been seriously hampered by the lack of any kind of uniformity in its measurement, and only a few workers know how to translate the results which they obtain into results comparable with those obtained with another instrument.

The suggestion has been made by Deeley and Parr that the unit of viscosity expressed in C. G. S. units should be called the "poise," in honor of Poiseuille, but the suggestion has not been adopted generally, and it is customary to simply speak of the "absolute" viscosity of a liquid. If the "poise" is adopted as the name of the absolute

unit, it has been suggested that we might use the decimal multiples and submultiples of this unit, and that then the centipoise—1 *cp* = 0.01 *p*—could be almost exactly the viscosity of water at 20° C. or 68° F. Thus for all practical purposes in the lubricating oil business it would be sufficiently near the truth to say that the viscosity expressed in centipoise is the specific viscosity; that is, the viscosity as compared with water at 20° C. as a standard liquid. The true viscosity of water in absolute units is 1.0042. Tables have been prepared by the use of which the true viscosity may be calculated from the number of seconds required with such extensively used instruments as the Saybolt Universal, Engler, and Redwood viscosimeters.

Steel in Wrought-iron Pipe. ANON. (*Iron Age*, vol. 97, No. 19. May 11, 1916.)—The detection of steel by means of etching with picric acid and a microscopical examination requires the preparation of a metallographic specimen and is a tedious operation, involving considerable time and the exercise of great care. Even when the wrought iron contains a large percentage of steel, the steel contents may often be missed, as there is nothing to indicate where the metallographic specimen should be prepared for microscopic examination. The test here described, developed by the A. M. Byers Company, of Pittsburgh, eliminates this uncertainty. It is not in itself conclusive as to the presence of steel, but by defining the areas most likely to contain steel it eliminates the necessity for further search and enables the investigator to proceed at once with the more elaborate preparation of the specimen for microscopic examination.

Three or four sample rings two or three inches in length are cut from different points of the pipe. The rings are submerged, one at a time, in a solution consisting, by volume, of hydrochloric acid 25 per cent., sulphuric acid 25 per cent., and water 50 per cent. After being left in the solution about one minute, the samples are rinsed in cold water and then with alcohol. Both ends of each sample should then be examined to discover bright streaks which are indicative of steel in the metal. As a rule, an examination of the surface of the metal will not show steel, as steel scrap is usually inserted in the middle layers of the fagot to prevent it from coming to the surface of the finished pipe. If no suspicious-looking streaks are found in the first ring etched, additional rings are tried. Three or four will usually reveal the steel scrap, especially if rings cut from different pieces of pipe are available. A "flat" or smooth surface is filed on the outside of the ring suspected of containing steel from the appearance of the end indications. Filing is stopped when the suspected steel band or bands are half filed away or when their maximum surface is exposed. It is not necessary to polish the surface to be examined. The flat is now etched in the same manner as the ends to disclose the steel bands. If any doubt now exists as to the composition of the bright streaks, the surface may be polished and etched with picric acid for microscopic examination.

PRESENTATION OF THE FRANKLIN AND ELLIOTT CRESSON MEDALS, MAY 17, 1916.

AT the stated meeting of the Committee on Science and the Arts, held March 1, 1916, the following resolutions were adopted:

Resolved, That the Franklin Medal be awarded to Theodore William Richards, Chem.D., M.D., Ph.D., Sc.D., LL.D., in recognition of his numerous and important contributions to inorganic, physical, and theoretical chemistry, and particularly his classical series of redeterminations of the atomic weights of the more important chemical elements.

Resolved, That the Franklin Medal be awarded to John J. Carty, E.D., D.Sc., in recognition of his long-continued activities in the telephone service, his important and varied contributions to the telephone art, his work in the establishment of the principles of telephone engineering, and his signal success in directing the efforts of a large staff of engineers and scientists to the accomplishment of the telephonic transmission of speech over vast distances.

Resolved, That the Elliott Cresson Medal be awarded to the American Telephone and Telegraph Company in recognition of its constructive and far-seeing policy in the development of the art of telephony; in the promotion of telephone engineering; in the establishment of its telephone system in every part of the United States, and for placing all of the States of the Union in speaking communication.

CORRESPONDENCE WITH MEDALLISTS.

THE FRANKLIN INSTITUTE.

PHILADELPHIA, PA., March 4, 1916.

Prof. Theodore William Richards,
Harvard University,
Cambridge, Mass.

SIR:—

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

Resolved, That The Franklin Medal be awarded to Theodore William Richards, Chem.D., M.D., Ph.D., Sc.D., LL.D., in recognition

of his numerous and important contributions to inorganic, physical, and theoretical chemistry, and particularly his classical series of redeterminations of the atomic weights of the more important chemical elements.

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on Wednesday, May 17, to receive this medal and certificate from our President.

I am, Respectfully,

(Signed) R. B. OWENS,
Secretary.

RBO : HMS

WOLCOTT GIBBS MEMORIAL LABORATORY, HARVARD UNIVERSITY.

THEODORE WILLIAM RICHARDS,
Director.

CAMBRIDGE, MASS., U. S. A., March 6, 1916.

Dr. R. B. Owens, Secretary,
The Franklin Institute of the State of Pennsylvania.
Philadelphia, Penna.

SIR:—

In formal acknowledgment of your favor of March 4, I beg to express my very high appreciation of the honour accorded to me by The Franklin Institute by the award of The Franklin Medal. This award is a great gratification to me, not only because it is the highest gift of this kind awarded by my native city, but also because I feel it is an especial honour to head the list of the American Franklin medallists for pure science.

I accept with pleasure the cordial invitation of the Institute to come to Philadelphia on May 17 to have the honour of receiving the medal and certificate from the President.

I beg to remain, my dear sir,

Sincerely yours,

(Signed) T. W. RICHARDS.

THE FRANKLIN INSTITUTE.

PHILADELPHIA, PA., March 14, 1916.

John J. Carty, Esq., E.D., D.Sc.,
American Telephone and Telegraph Company,
New York, N. Y.

SIR:—

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in

physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

> *Resolved*, That The Franklin Medal be awarded to John J. Carty, E.D., D.Sc., in recognition of his long-continued activities in the telephone service, his important and varied contributions to the telephone art, his work in the establishment of the principles of telephone engineering, and his signal success in directing the efforts of a large staff of engineers and scientists to the accomplishment of the telephonic transmission of speech over vast distances.

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on Wednesday, May 17, to receive this medal and certificate from our President.

I am, Respectfully,

(Signed) R. B. OWENS,
Secretary.

RBO : S

FIFTEEN DEY STREET.

NEW YORK, March 17, 1916.

Dr. R. B. Owens, Secretary,
The Franklin Institute,
Philadelphia, Penna.

DEAR SIR:—

I have the honor to acknowledge the receipt of your communication of the 14th of this month, advising me that The Franklin Institute has awarded to me The Franklin Medal, founded for the recognition of those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications.

I take this first opportunity to express to The Franklin Institute my grateful appreciation of this great distinction which it has so generously conferred upon me. Knowing the jealous care with which this honor is bestowed and understanding the high standards to which the holders of this medal must conform, my feelings of pleasure and satisfaction and gratitude have been accompanied by the resolve to do everything in my power to be worthy of enrolment among the Franklin medallists.

It gives me great pleasure to say that I accept the cordial invitation which you have extended to me on behalf of the management to come to the Institute on Wednesday, May 17, to receive The Franklin Medal and certificate from the President.

As a slight token of appreciation on the part of my company and on my own part, I am making plans for a telephone demonstration as a part of the ceremonies attending the presentation of the medal, which will exemplify the advancement in the art of telephony, which has received such distinguished recognition from The Franklin Institute. I shall communicate with you within a short time concerning the nature of the telephone demonstration and shall be glad to receive your suggestions in regard to it.

Meanwhile permit me to thank you for the most courteous consideration which you have shown to me.

Very sincerely yours,

JJC-EMR (Signed) JOHN J. CARTY.

THE FRANKLIN INSTITUTE.

PHILADELPHIA, PA., March 8, 1916.

Theodore N. Vail, Esq., President,
American Telephone and Telegraph Company,
New York City, N. Y.

SIR:—

I have the honour to inform you that The Franklin Institute has awarded to the American Telephone and Telegraph Company its Elliott Cresson Medal, founded in 1848 for the "recognition of discovery or original research adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery and invention, and methods or products embodying substantial elements of leadership in their respective classes."

The award is minuted as follows:

> *Resolved*, That the Elliott Cresson Medal be awarded to the American Telephone and Telegraph Company in recognition of its constructive and far-seeing policy in the development of the art of telephony; in the promotion of telephone engineering; in the establishment of its telephone system in every part of the United States, and for placing all of the States of the Union in speaking communication.

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on Wednesday, May 17, to receive this medal and certificate from our President.

I am, Respectfully,

(Signed) R. B. OWENS,
Secretary.

RBO : S

15 DEY STREET,
NEW YORK.

March 9, 1916.

R. B. Owens, Esq.,
Secretary, Franklin Institute,
Philadelphia, Pa.

MY DEAR SIR:—

I beg leave to acknowledge the receipt of yours of March 8.

The honor which your Institute has decided to confer upon the American Telephone and Telegraph Company will be appreciated very highly, and unless something arises which will make it absolutely impossible, you may be sure that I shall be present on May 17.

This is not an official acknowledgment, but merely a personal acknowledgment to you of the receipt of your letter.

I have instructed our people to send you a printed copy of the address delivered at the Geographic Society Banquet as soon as it comes from the printer.

Sincerely yours,
(Signed) THEODORE N. VAIL.

AMERICAN TELEPHONE AND TELEGRAPH COMPANY,
15 Dey Street.

NEW YORK, March 22, 1916.

Mr. R. B. Owens, Secretary,
The Franklin Institute,
Philadelphia, Pennsylvania.

DEAR SIR:—

Your letter of the 8th instant, advising us that The Franklin Institute had awarded to this company its Elliott Cresson Medal, was acknowledged by President Vail before his departure for the South, and handed to me for further attention.

The Board of Directors of this company, at a meeting held yesterday, directed me to convey to you and to The Franklin Institute an expression of this company's appreciation of the great honor bestowed upon it by your distinguished society, and to say that this recognition of the company's efforts to realize its desire to be of service to the American people is exceedingly gratifying, and will be a source of inspiration to our entire organization.

Respectfully yours,
(Signed) U. N. BETHELL,
Senior Vice-President.

PROGRAMME OF MEETING, MAY 17, 1916.

Presentation of the Franklin Medal to THEODORE WILLIAM RICHARDS, Chem.D., M.D., Ph.D., Sc.D., LL.D., Director, Wolcott Gibbs Memorial Laboratory, Harvard University.

Address by Dr. Richards, "The Fundamental Properties of the Elements."

Presentation of the Franklin Medal to JOHN J. CARTY, E.D., D.Sc., Chief Engineer American Telephone and Telegraph Company.

Address by Dr. Carty, "The Telephone Art."

Presentation of the Elliott Cresson Medal to American Telephone and Telegraph Company, Theodore N. Vail, President.

Address by Mr. Vail.

PRESENTATION OF THE FRANKLIN MEDALS TO DOCTORS THEODORE WILLIAM RICHARDS AND JOHN J. CARTY.

In calling the meeting to order the President of the Institute announced that the business of the meeting would be the annual presentation of the Institute's highest awards in recognition of distinguished scientific and technical achievement, and recognized Dr. Harry F. Keller, who made the following statement relative to the work of Professor Richards:

"*Mr. President:* We are gathered here this afternoon in this venerable Hall to witness the formal presentation by you, on behalf of The Franklin Institute, of the highest awards within its gift to those distinguished men whom the Committee on Science and the Arts has this year chosen and recommended as most worthy of such honor in view of their great achievements in science.

This is the second occasion on which two impressions of the beautiful Franklin Medal are presented by you in accordance with the wishes of the founder, Samuel Insull, Esq., who in his deed of gift has stipulated that "it shall be awarded from time to time to those workers in physical science and technology, without regard of country, whose efforts, in the opinion of the Institute, have done most to advance our knowledge of physical science and its applications." It is a matter of great and peculiar gratification to our Institute, Mr. President, that in this instance both of the medallists should be Americans, representing, as they do, the

highest achievements—in the one case, of research and discovery in pure science, and, in the other, in the practical applications of physical science.

On the other side of the Atlantic the terrible war has most seriously interfered with—nay, almost halted—scientific progress: it has directed scientific knowledge and human ingenuity in the belligerent countries toward the devising of instruments of destruction, instead of their normal mission of advancing civilization. But it is quite improbable that even if by some miracle this devastating struggle could have been prevented, and the work of scientists had been allowed to proceed along the former lines, even then, I say, it is unlikely that our choice of medallists would have been different. We are satisfied that, without making any reservation or allowance for the present conditions in Europe, they must be counted as luminaries of the first magnitude among living scientists.

I consider it a great privilege, Mr. President, to represent the Science and Arts Committee and to introduce the medallists on this occasion.

In spite of the vast expenditures for their armies and navies in times of peace, the governments of European countries have long realized that liberal appropriations to their institutions of learning and for the promotion of scientific research is money well invested: in our country, on the other hand, the endowment of universities and research laboratories is largely dependent upon the munificence of private individuals. Nevertheless, the advancement of science in American laboratories, and by American workers, especially in recent years, has been quite abreast of that in European countries; and in not a few branches of science we are proud to point to our compatriots as the peers of those abroad. The eminent chemist who is to receive the Franklin Medal is a striking case in point. Though still in the prime of life, and looking forward, perhaps, to even greater achievements, his contributions to chemical science are universally recognized as second to none, either in number or importance, made by any contemporary investigator. Only recently the Nobel Prize of 1914 in chemistry was awarded to him, and the oldest and most famous institutions of learning in every part of the world have fairly showered upon him their highest honors and distinctions. More than a dozen universities have conferred upon him their

honorary degrees; learned societies, both here and abroad, have vied with one another in electing him a member or officer; and the most highly prized trophies of chemistry, such as the Davy, the Faraday, and the Willard Gibbs Medals, have been bestowed upon him. With the award of the Franklin Medal the last great link in this great chain of honors would seem to be added.

And it seems peculiarly appropriate that this should be done in his native city. He was born in Germantown, in 1868, the son of a well-known painter of landscapes and marines. It was there, also, that he spent most of his childhood, and where his gifted mother conducted his early education. His curiosity and interest in experimentation and science were early awakened by friends of the family, among them Dr. John Marshall, of the University of Pennsylvania. At the age of fifteen he entered the Sophomore class at Haverford College, where he first seriously studied chemistry under Dr. Lyman B. Hall. After graduation in 1885, he studied Greek and entered the Senior class in Harvard, as its youngest member, in the autumn of the same year.

Since then his career, with the exception of a few and comparatively short interruptions, has had its scene in Harvard University. Graduating as A.B. in 1886, *summa cum laude*, with highest honors in chemistry, he received a fellowship in the graduate department and conducted research work under Josiah Parsons Cooke, taking the degrees of A.M. and Ph.D. in 1888. The following year he spent in Europe, visiting eminent chemists and important laboratories in various countries, and familiarizing himself with special methods of analysis and research. Returning to Harvard in 1889, he was appointed assistant, and from this position he gradually rose to that of Professor of Chemistry and Director of the recently founded Wolcott Gibbs Memorial Laboratory. The only prolonged absences from Harvard were for the purpose of studying with some of the German masters, and, in 1907, when he was selected as Visiting Professor to the University of Berlin. Teaching a group of advanced students his methods of experimentation and research, he made a profound impression on both the students and professors. It was little short of a revelation to the German chemists that the time had arrived for reciprocity between the American and German universities in the teaching of the most advanced thought and practice in chemical research.

To sketch and characterize the work of our medallist in a few sentences—and that is all I can here attempt to do—is a difficult, an almost hopeless, task. If you consider that ever since he graduated from Harvard in 1886 he has continuously and indefatigably been active as a teacher and investigator; that his fertile brain has planned and directed the work of great numbers of assistants and students; that his contributions to science extend over vast domains of inorganic, physical, analytical, and theoretical chemistry, and in many cases far beyond the border-line of physics; if you consider how numerous, divergent, and extended are the paths he has travelled, you will understand that only a very few of the high lights can here be pointed out. Best known, and, in certain respects, most important, are the researches on the atomic weights of more than twenty of the chemical elements. These elements were not chosen at random, but very carefully selected with a view to solve chemical problems of fundamental importance. The papers published on this work extend over many years, and must be counted among the classics of chemical literature. They reveal the masterly reasoning of the author, his fertile scientific imagination, his resourcefulness and skill as an experimenter. They abound in the description of new observations, new methods, and new forms of apparatus. The atomic weights themselves are determined with the utmost precision that the resources of modern science permit. It was from the investigation of the fundamental properties of the elements that most of his other researches took their starting-points. Among them are the studies of the compressibility of elements and compounds; of the changes in atomic volume; of the birth of crystals as revealed by micro-photography and the kinetoscope; of thermo-chemical, electro-chemical, and, lately, also of radio-chemical problems. His hypotheses concerning the sour taste of acids and the compressibility of atoms are noteworthy contributions to theoretical chemistry, and he has also devised one of the best methods of teaching elementary chemistry.

I am aware, Mr. President, that this brief summary is far from adequate to impress you and this brilliant audience with the far-reaching importance of our medallist's work in the light it has shed upon the fundamental properties of the elements and upon the relationships of matter and energy. I trust, however, that these deficiencies will be made up when we listen to the address the

medallist, Dr. Theodore William Richards, has prepared for this occasion."

Due to illness, Dr. Richards was unable to be present, and the President announced that the medal and accompanying certificate would be forwarded to him. Dr. George A. Hoadley then read the following address for Professor Richards:

THE ESSENTIAL ATTRIBUTES OF THE ELEMENTS.

BY

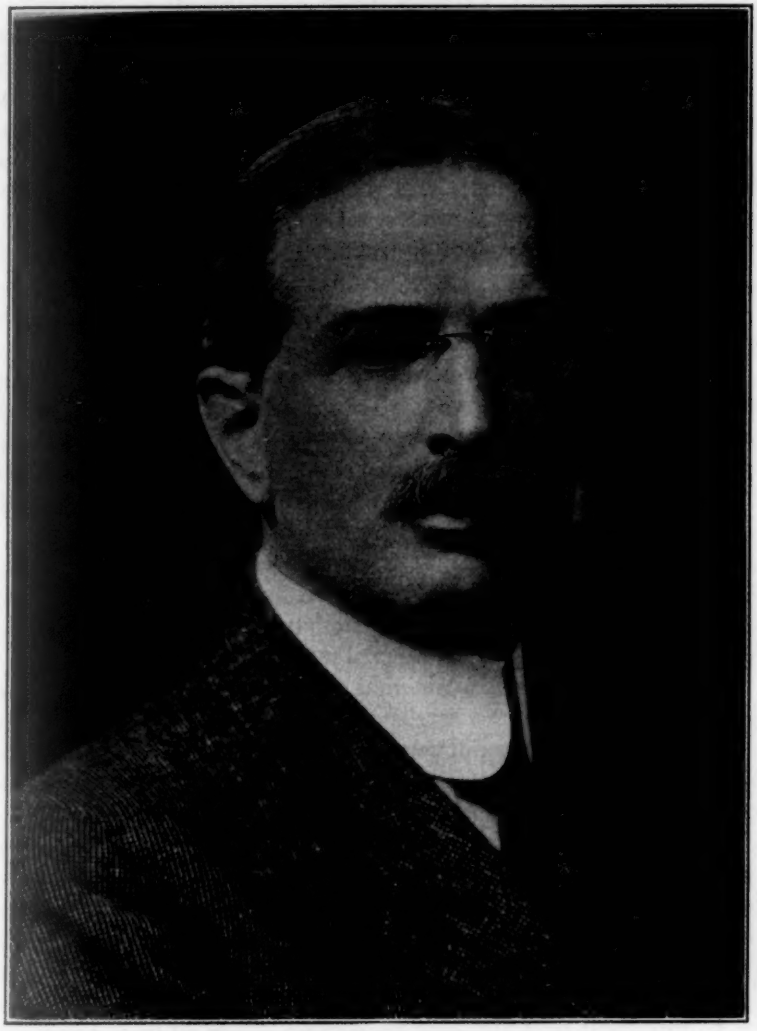
THEODORE W. RICHARDS, CHEM.D., M.D., PH.D., SC.D., LL.D.,

Director, Wolcott Gibbs Memorial Laboratory, Harvard University.

We come together to-day, in this world-renowned Institute, founded in honor of one of the greatest of our countrymen, to participate in an annual celebration of progress in pure and applied science. Franklin himself would have heartily approved of such an annual celebration; he was deeply interested in the study of Nature, and profoundly convinced of the importance to humanity of exact knowledge and its practical application. Inspired by his conviction of the usefulness of science, he founded here in Philadelphia the oldest American scientific society, and here he performed the first significant experiments in physics of the New World. He would have eagerly supported the Institute in its aims and activities, and he is fittingly commemorated in its name.

To be included in this celebration of scientific advance in the home of Franklin, my own native city, is a privilege; and I beg to express my hearty appreciation of the very great honor which the Institute has conferred upon me.

As the title on the program indicates, my pleasant duty now is to speak to you on the fundamental properties of the elements, which have formed the chief subject of my chemical and physical studies. At the outset one may well ask: What are the elements, and what shall we designate as their fundamental properties? In these iconoclastic days several of our old scientific idols seem to have been shattered. If uranium and radium are only transitory, may not the other so-called "elements" also be slowly decomposing? In this case, ought we to count them as elements at all? Moreover, if, as some suppose, the atom is made up of nothing but electrons (positive and negative), what has become of the old atomic theory?



T. W. Richards

These questions, disturbing although they may seem to be, are easily answered. Perhaps, from a philosophical and etymological point of view, the chemical atom no longer deserves its name; but the fact remains that in all the ordinary affairs of life our relations with the chemical elements primarily concerning us are unchanged by all the fascinating new knowledge. These same old elements remain as permanent as they ever were; and the only satisfactory explanation of the definite proportions by weight in which they combine is now, as of yore, the assumption of ultimate, undestroyed (if not indestructible) particles or chemical "atoms." The atomic theory is indeed even more convincing to-day with regard to mundane chemical affairs than it was before the dawn of radio-activity.

Of course, no one pretends nowadays that the chemical elements are to be considered as absolutely incapable of decomposition. Even supposing, however, that in the hottest stars some of them disintegrate, on earth, at least, they are amazingly permanent. It is concerning the earthly chemical elements, therefore—the old-fashioned kind of half a century ago—that I have to speak.

These elementary chemical substances build up everything about us, as well as our own bodies. It has always seemed to me, therefore, that the fundamental attributes which determine their behavior are worthy of very careful scrutiny.

Among the most fundamental of attributes, if not the most significant of all, is the tendency possessed by the elements to combine in definite proportions by weight. This we explain, as already stated, by the assumption that all matter is made up of atoms. One cannot believe that these atoms should have anything so important as their weight decided by mere chance or accident. Therefore, I chose the study of the atomic weights as the first of the fundamental properties to be investigated, and perhaps half of my time during the last thirty years has been devoted to this subject.

Great accuracy in the work was sought for several reasons, the most important of which was an earnest desire to find if possible the suspected mathematical relationship between these fundamental quantities. Such a relationship, if discovered, would greatly deepen our insight; and if it is to be found, the data to be compared must be determined as accurately as possible.

Another reason for taking great pains in determining atomic

weights is the fact that these figures are used by chemists throughout the world in their daily work oftener than any other series of data. All the manifold happenings of Nature occur in material built up of these same atoms. If we are to analyze or synthesize, or in any way have to do with the quantitative relations of reacting chemical substances under any circumstances, we must ultimately turn to the atomic weights for help. It is not too much to say that the atomic weights are the basis of quantitative chemistry.

More than two thousand years ago Plato said: "If from any art that which concerns weighing, measuring, and arithmetic is taken away, little remains of that art." To-day we may paraphrase this saying as follows: "If from chemistry are taken away the atomic weights (or other numerical data representing the same definite proportions), little will remain of that science." As a science becomes more scientific it becomes more quantitative, and greater accuracy in the determination of its fundamental mathematical basis is required.

There is not time this afternoon to go into the details of many determinations of nearly thirty atomic weights carried out during as many years at Harvard. The effort was made to build upon the basis provided by the careful work of Berzelius, Marignac, and Stas, with the help of the new discoveries in physical chemistry concerning solubility, hydrolysis, adsorption, and solid solution. Metals were compared, as to their combining proportions, especially with chlorine, bromine, and iodine; moreover, many other careful comparisons likewise were made, as, for example: oxygen with silver through lithium chloride and lithium perchlorate; silver into nitrogen and sulphur through silver nitrate and sulphate; oxygen with carbon and sulphur sodium carbonate and sulphate, and many others. These, taken together, tend to put our whole table of atomic weights upon a stabler basis. The elements of which the atomic weights have been determined under my own immediate supervision are the following: copper, barium, strontium, calcium, magnesium, zinc, nickel, cobalt, iron, uranium, cæsium, sodium, potassium, chlorine, nitrogen, silver, sulphur, carbon, lithium, and radio-lead. To these should be added, as part of the Harvard contribution, those studied by my most energetic pupil in this line of work, Prof. G. P. Baxter, long since an independent investigator on his own account: arsenic, bromine,

cadmium, chromium, iodine, lead, meteoric iron and nickel, manganese, neodymium, praseodymium, and phosphorus. The most interesting outcome of my work is perhaps the discovery that lead from radio-active minerals possesses an atomic weight distinctly less than that of ordinary lead—206.1 instead of 207.2—although it gives the same spectrum.

If I were to sum up in a few words the lessons of these protracted investigations, I should be inclined to say that the secret of success in the study of atomic weights lies in carefully choosing the particular substances and processes employed, and in checking every operation by parallel experiments so that every unknown chemical and physical error will gradually be ferreted out of its hiding-place. The most important causes of inaccuracy are: the solubility of precipitates and of the material of containing vessels; the occlusion of foreign substance by solids, and especially the presence of retained moisture in almost everything. Each of these disturbing circumstances varies with each individual case. Far more depends upon the intelligent choice of the conditions of experiment than upon the mechanical execution of the operations, although that, too, is important. I have often quoted the innocent remark which has occasionally been made to me: "What wonderfully fine scales you must have to weigh atoms!" and have endeavored to point out that the purely chemical work, which precedes the introduction of the substance into the balance-case, is much more important than the mere operation of weighing.

Laboratory work alone can furnish us with accurate values of the atomic weights. No speculative method involving higher mathematics has as yet been able to solve definitively the cosmic puzzle of their relative magnitudes. In this direction, as in many others, chemistry is still largely an inductive science. When we have discovered the realities, we shall be in a position to attempt to explain them. In the meantime more accurate views, discovered little by little through patient investigation, will be of use to the thousands of men throughout the world who daily employ these fundamental data of chemistry.

Matter possesses not only the fundamental properties of weight and mass, measured (from the chemical point of view) by the combining proportions of the elements, but also an equally fundamental attribute which causes it to occupy space. Thus, side by side with the study of weight and mass, the study of volume de-

serves close attention. This latter property is more changeable and more puzzling in its varied manifestations than the constant attributes of weight and mass. Almost every solid expands, occupying more space as it is heated, expands yet more in the act of melting, and finally swells up into an altogether disproportionate volume when it is converted into vapor. In each of these states of matter the application of pressure produces a lessening of the volume—very small, but still perceptible in the case of solids, usually greater in the case of liquids, and still very much greater in the case of gases. The behavior of gases is very similar in each case: here the molecules must be far apart. On the other hand, solids and liquids behave in a manner entirely different from gases and entirely different from one another. The molecules must be very near one another, and the specific nature of each must come greatly into play. Even for any single substance the space-filling relations of the solid and liquid form are highly complex, and when comparison is made between different substances the complexity is vastly increased; yet none of these varying manifestations of the property of occupying space can be accidental. Each must have its inner significance, and the relation of each to the other cannot but be fundamentally connected with the ultimate nature of the substance concerned. Some of the relations are opened to us by the science of thermodynamics; but many of the data must be found, like the atomic weights, by experiment alone.

These considerations led me, nearly twenty years ago, to begin the study not only of the space occupied by the elements, especially in their liquid and solid states of aggregation, but also of many other related fundamental properties of the elements and their compounds, including the effect of increasing temperature and increasing pressure. Some of the data needed in this study had already been provided by the preceding work of others, but particularly in the case of compressibility, of which I wish especially to speak, very few data had been gathered even as recently as fifteen years ago. Only three or four elements had been carefully studied, and these by methods of doubtful efficacy. Hence the first step was to devise a simple and accurate method capable of determining the exceedingly small compressibilities of the solid elements. This method was devised in 1903, and with its help the compressibilities of nearly forty elements have been determined with sufficient accuracy to trace with some precision their relations

to one another and to the bulk occupied by these same elements. Bridgman has since carried the determination of a few of these to much higher pressures, with confirming results.

The outcome is highly interesting. If the elements are arranged in the order of their atomic weight, we find that the compressibilities show a very well-marked alternating periodic increase and decrease as the atomic weight progresses. This fluctuation parallels in remarkable fashion the periodicity of the atomic volumes noticed long ago by Lothar Meyer. It appears that when an element has a large atomic volume (that is to say, when the bulk occupied by its atomic weight in grammes is large) the compressibility also is large, and *vice versa;* and the changes are of the same order in the two cases. That these two properties are fundamentally connected no one can doubt after studying the parallel curves showing their similar progression with increasing atomic weight. Neither can one doubt that in the tracing of this parallelism a real step has been made in the study of the nature of the element.

Other properties, more or less related, also have been shown to have analogous rhythms, but lack of time prevents any attempt to explain them.

One may well ask: Can any conceivable interpretation be found for such parallel rhythms, analogous to Dalton's interpretation of the combining weights of the elements? In other words, can we refer effects concerned with the space occupied by gross matter to the atoms themselves, somewhat as the combining proportions of the elements are refered to the weights of the atoms? It seems to me that this can be done.

If one assumes that the practical bulk of the atoms in solids and liquids is compressible, most of these results fit naturally into their expected places. Those atoms which are much distended (that is to say, have large atomic volume) would be expected to be the most compressible. We should expect also to find that increasing chemical affinity, by pulling the atoms more and more together, would likewise cause compression and, therefore, diminish volume; and cohesive affinity would have the same effect. There is much evidence to show that this interpretation is a reasonable one, but time forbids again that the details should be entered into here. The hypothesis is pragmatic; it considers, not the hypothetical space which may or may not be occupied by an imag-

inary centre or core in the atom, but rather the space which the atom actually requires in solids and liquids. That this space is definite and significant is proved beyond cavil by such curves as those to which I have referred, as well as many other facts concerning solids and liquids. One may well hope that the combined following of this trail may lead one to heights from which a broader view of the materials constructing the universe may be obtained. But even if the hypothesis should some time be found wanting, it has served already a purpose helpful to progress, for it has stimulated many researches leading to the acquisition of new facts. These will stand in the future, whatever may be the fate of the theory.

Do these investigations concerning ultimate properties of things and these hypotheses concerning the correlation of the properties seem to be remote from the pressing problems of humanity? Not so. We must remember that applied science follows in the footsteps of theoretical science. The laws of chemistry cannot be adequately applied until they have been discovered. Only by researches delving into the hidden secrets of Nature by some such processes as these can new discoveries in the realm of pure science be made; and no one can tell how great may be the gain to the philosophy of Nature, as well as to the daily lives of men, ultimately resulting from new knowledge thus gained.

The vital importance of chemistry to modern civilization is well known to this distinguished audience. Some one has wisely remarked that, whereas the nineteenth century was primarily devoted to advance in mechanical and electrical directions, the twentieth century bids fair to be an essentially chemical century. In war—now, alas! devastating the earth—as well as in the lasting peace for which we hope, chemistry is bound to play an all-important part. We perceive that every manufacture is concerned with chemical substances; we realize that recent chemical discoveries have revolutionized the preparation of many things essential to our life and have initiated entirely new industries of great importance and benefit to mankind. The great war has only intensified our appreciation of these facts. We recognize also that even we ourselves, so far as our material existence is concerned, are chemical machines, and that our every thought and act is intimately bound up with chemical reactions, without which neither thought nor act could come into being. Let us hope that

the triumphs of chemistry in the future will be used not only for furthering manufacture and agriculture, thereby rendering life more comfortable and prosperous; but also, above all, for advancing hygiene and medicine to a point where the physician will be able really to understand the complex anomalies which confront him every day. Let us hope, too, that with this practical progress may be united the growth of a broader and saner philosophy of Nature, founded upon a truer knowledge of the materials composing the universe and of the energy which animates it. To such ends, full of blessing to humanity, let us dedicate the science in the future.

In introducing Dr. John J. Carty, Dr. Keller said:

"*Mr. President:* In discussions on the teaching of science in our schools and colleges there is often a tendency on the part of educators to underestimate, and even to belittle, the value of applied science. Only a few weeks ago I listened to an entertaining, and in some respects quite illuminating, after-dinner speech in which the applications of scientific knowledge were referred to as "*ephemeral,*" while the speaker, an eminent biologist, laid great stress upon the *permanent* value of the results of scientific investigation. Such statements, Mr. President, are apt to lead to conclusions which are quite erroneous, and certainly at variance with the traditions and the beliefs of this venerable Institute, devoted to Science and the Mechanic Arts. While we may readily concede that a new fact or principle, definitely established, is a permanent addition to the sum of human knowledge, and that such a fact or principle may lead to applications that minister to our material needs, we also maintain that these practical applications are no less permanent additions to human progress and civilization. Whilst paying homage to the Faradays and the Hertzes, to the Lavoisiers and the Liebigs, who have made the fundamental discoveries in electricity and chemistry, let us not forget to honor those who by their inventive genius and engineering skill have utilized these discoveries in creating and developing the marvellous industries of the electrical arts and the chemical manufactures. Just as there are fundamental scientific discoveries, so there are also basic inventions in the arts. The printing press that turns out the enormous editions of our daily papers

still embodies the crude but basic device of Gutenberg; and the wonders of the transmission of human speech, which it is our rare good fortune to witness here to-day, would scarcely have been possible without the pioneer work of Alexander Graham Bell and Guglielmo Marconi.

But it is a far cry, an almost inconceivable advance, from the infant invention of 1876, which then enabled Professor Bell to talk to his assistant, Mr. Watson, two miles away, to the vast Bell Telephone System of 1916, which, with its vast network of lines, covers all the States of the Union, and, with the epoch-making wireless extension during the past year, now permits one not only to speak without effort and distinctly across the continent, but to distant islands and continents and to ships at sea. It sounds like a fairy tale, indeed, to be told that messages sent from Arlington by wireless have been heard and the voice of the speaker recognized at Honolulu, nearly five thousand miles away. To tell the story of the marvellous development of the art of telephony here in America, the country of its birth, is to narrate the rise and development of an entirely new science—that of telephone engineering. While a great army of engineers, inventors, financiers, and others have played more or less conspicuous parts in this development and contributed their share to the recorded achievements, the dominating figure in the story is that of him who is now the chief engineer of the American Telephone and Telegraph Company, and who, in recognition of his life's work, is to receive from you, Mr. President, the Franklin Medal.

The story of his life is simple; its great and dramatic events are his scientific achievements and their public recognition. He was born in Cambridge, Mass., in 1861. Circumstances did not permit him to continue his education after his graduation from the Cambridge Latin School. A natural bent for mechanics was doubtless the reason for his seeking employment with the Telephone Dispatch Company of Boston. Thus he entered the telephone business as a boy of eighteen, and during the eight years he remained with this concern he made a number of valuable contributions to the telephone art, among them the construction of a multiple switchboard, at that time the largest ever put in use, and of the first metallic circuit multiple switchboard, of which certain features are retained in all the boards of to-day. In 1887 he was placed in charge of the cable department of the

Western Electric Company in the East, and subsequently of the switchboard department of this company. During these years he made many important improvements in cable laying and manufacture, as well as in the design of switchboards. In 1888 he had perfected a "common battery" system, by which two or more telephone circuits could be operated; and it was from this that the present standard common battery system was evolved.

While thus engaged in the solution of various engineering problems, he also devoted some of his time to scientific research. A paper read by him in 1889, and entitled "A New View of Telephone Induction," called attention to the fact that electrostatic induction is the main factor in producing cross-talk, and that this cross-talk may be prevented by the insertion of a telephone at the "silent" or "neutral" point of the circuit. In a later communication he explained how by twisting and transposing telephone lines they may be rendered free from inductive disturbances.

In 1889 he entered the service of the Metropolitan Telephone and Telegraph Company, now the New York Telephone Company. In this position he accomplished the great tasks of organizing the various technical departments, of building up the staff of the company, and of repeatedly reconstructing and modernizing the entire plant. The extensions he then provided for constitute the present comprehensive telephone system of New York.

In 1887 he was appointed to the position he occupies to-day, that of chief engineer of the American Telephone and Telegraph Company. He thus became responsible for all the engineering work, both of plant and traffic, of the great Bell System, and all the great developments that have since been carried to a successful conclusion were made under his direction.

Among these is the longest underground telephone cable in the world, connecting Boston, New York, and Washington. Until 1912 the steady improvement of the lines and apparatus permitted the extension of the service to Denver, Colo., a distance of 2100 miles from New York City. Three years later, in January, 1915, the dedication to the use of the public of the completed transcontinental telephone circuits from San Francisco to New York and Boston was held, with impressive ceremonies, in the presence of a most distinguished gathering.

With achievements such as these it might be supposed that even the most ambitious of mortals would be content to rest upon

his laurels. Not so with our medallist. On the heels of the completion of the transcontinental telephone circuits came the announcement that this wizard had accomplished and demonstrated what only a few years ago the wildest flights of the scientific imagination would scarcely have suggested as possible. I refer to the transmission of the speaking voice by a wireless telephone to places outside and far beyond the network of the Bell System. This epoch-making achievement, supplementing as it does the wire service, is now well under way to bring about the ultimate goal of telephony—the establishment of a Universal System.

Such, Mr. President, are the services for the benefit of mankind which the master mind of the telephone art has rendered as the results of a lifetime of indefatigable labor, guided by a scientific imagination of the highest order. But a few years ago his name was comparatively unknown outside of his profession, to-day it is one to conjure with in every quarter of the Globe: it is Dr. John J. Carty, Chief Engineer of the American Telephone and Telegraph Company, whom I have the honor to introduce to you as recipient of The Franklin Medal."

The *President,* in presenting the Franklin Medal to Dr. John J. Carty, said: "I have the honor, in the name of The Franklin Institute, as recommended by its Committee on Science and the Arts, and in recognition of your distinguished services to mankind, rendered in the field of science, to present to you the Franklin Medal, the highest honor in the gift of the Institute."

After expressing his appreciation of the honor conferred upon him, Dr. Carty read the following address:

THE TELEPHONE ART.

BY

JOHN J. CARTY, E.D., D.SC.,

Chief Engineer, American Telephone and Telegraph Company.
Member of the Institute.

More than any other, the telephone art is a product of American institutions and reflects the genius of our people. The story of its wonderful development is a story of our own country. It is a story exclusively of American enterprise and American progress, for, although the most powerful governments of Europe

have devoted their energies to the development and operation of telephone systems, great contributions to the art have not been made by any of them. With very few exceptions, the best that is used in telephony everywhere in the world to-day has been contributed by workers here in America.

It is of peculiar interest to recall the fact that the first words ever transmitted by the electric telephone were spoken in a building at Boston, not far from where Benjamin Franklin first saw the light. The telephone, as well as Franklin, was born at Boston, and, like Franklin, its first journey into the world brought it to Philadelphia, where it was exhibited by its inventor, Alexander Graham Bell, at the Centennial Exhibition in 1876, held here to commemorate the first hundred years of our existence as a free and independent nation.

It was a fitting contribution to American progress, representing the highest product of American inventive genius, and a worthy continuance of the labors of Franklin, one of the founders of the science of electricity as well as of the Republic.

Nothing could appeal more to the genius of Franklin than the telephone, for not only have his countrymen built upon it an electrical system of communication of transcendent magnitude and usefulness, but they have made it into a powerful agency for the advancement of civilization, eliminating barriers to speech, binding together our people into one nation, and now reaching out to the uttermost limits of the earth, with the grand aim of some day bringing together the people of all the nations of the earth into one common brotherhood.

On the tenth day of March, 1876, the telephone art was born, when, over a wire extending between two rooms on the top floor of a building in Boston, Alexander Graham Bell spoke to his associate, Thomas A. Watson, saying: "Mr. Watson, please come here; I want you." These words then heard by Mr. Watson in the instrument at his ear constitute the first sentence ever received by the electric telephone. The instrument into which Mr. Bell spoke was a crude apparatus, and the current which it generated was so feeble that, although the line was about a hundred feet in length, the voice heard in the receiver was so faint as to be audible only to such a trained and sensitive ear as that of the young Mr. Watson, and then only when all surrounding noises were excluded.

Following the instructions given by Dr. Bell, Mr. Watson

John J. Carty

with his own hands had constructed the first telephone instruments and ran the first telephone wire. At that time all the knowledge of the telephone art was possessed exclusively by these two men. There was no experience to guide and no tradition to follow. The founders of the telephone, with remarkable foresight, recognized that success depended upon the highest scientific knowledge and technical skill, and at once organized an experimental and research department. They also sought the aid of university professors eminent for their scientific attainments, although at that time there was no university giving the degree of Electrical Engineer or teaching electrical engineering.

From this small beginning there has been developed the present engineering, experimental, and research department which is under my charge. From only two men in 1876, this staff has, in 1915, grown to more than 600 engineers and scientists, including former professors, post-graduate students, and scientific investigators, graduates of nearly a hundred American colleges and universities, thus emphasizing in a special way the American character of the art. The above number includes only those devoted to experimental and research work and engineering development and standardization, and does not include the very much larger body of engineers engaged in manufacturing and in practical field work throughout the United States. Not even the largest and most powerful government telephone and telegraph administration of Europe has a staff to be compared with this. It is in our great universities that anything like it is to be found, but even here we find that it exceeds in number the entire teaching staff of even our largest technical institutions.

A good idea may spring up in the mind of man anywhere, but as applied to such a complex entity as a telephone system, the countless parts of which cover a continent, no individual unaided can bring the idea to a successful conclusion. A comprehensive and effective engineering and scientific and development organization such as this is necessary, and years of expensive work are required before the idea can be rendered useful to the public.

But, vital as they are to its success, the telephone art requires more than engineers and scientists. So we find that in the building and operation and maintenance of that vast continental telephone system which bears the name of Bell, in honor of the great inventor, there are at work each day more than 170,000 employees,

of which nearly 20,000 are engaged in the manufacture of telephones, switchboards, cables, and all of the thousands and tens of thousands of parts required for the operation of the telephone system of America.

The remaining 150,000 are distributed throughout all of the states of the Union. About 80,000 of these are women, largely telephone operators; 50,000 are linemen, installers, cable splicers, and the like, engaged in the building and maintaining of the continental plant. There are thousands of other employees in the accounting, legal, commercial, and other departments. There are 2100 engineers located in different parts of the country. The majority of these engineers have received technical training in American technical schools, colleges, and universities. This number does not include, by any means, all of those in the other departments who have received technical or college training.

In view of the technical and scientific nature of the telephone art, an unusually high-grade personnel is required in all departments, and the amount of unskilled labor employed is relatively very small. No other art calls forth in a higher degree those qualities of initiative, judgment, skill, enterprise, and high character which have in all times distinguished the great achievements of America.

In 1876 the telephone plant of the whole world could be carried away in the arms of one man. It consisted of two crude telephones like the one now before you, connected together by a wire of about one hundred feet in length. A piece cut from this wire by Mr. Watson himself is here in this little glass case.

At this time there was no practical telephone transmitter, no hard-drawn copper wire, no transposed and balanced metallic circuit, no multiple telephone switchboard, or telephone switchboard of any kind, no telephone cable that would work satisfactorily; in fact, there were none of the multitude of parts which now constitute the telephone system.

The first practical telephone line was a copy of the best telegraph line of the day. A line wire was strung on the poles and housetops, using the ground for the return circuit. Electrical disturbances, coming from no one knows where, were picked up by this line. Frequently the disturbances were so loud in the telephone as to destroy conversation. When a second telephone line was strung alongside the first, even though perfectly insulated,

another surprise awaited the telephone pioneer. Conversation carried on over one of these wires could plainly be heard on the other. Another strange thing was discovered. Iron wire was not as good a conductor for the telephone current as it was for the telegraph current. The talking distance, therefore, was limited by the imperfect carrying power of the conductor and by the confusing effect of all sorts of disturbing currents from the atmosphere and from neighboring telephone and telegraph wires.

These and a multitude of other difficulties, constituting problems of the most intricate nature, impeded the progress of the telephone art, but American engineers, by persistent study, incessant experimentation, and the expenditure of immense sums of money have overcome these difficulties. They have created a new art, inventing, developing, and perfecting, making improvements great and small in telephone, transmitter, line, cable, switchboard, and every other piece of apparatus and plant required for the transmission of speech.

As the result of nearly forty years of this unceasing, organized effort, on the 25th of January, 1915, there was dedicated to the service of the American public a transcontinental telephone line, 3600 miles long, joining the Atlantic and the Pacific, and carrying the human voice instantly and distinctly between San Francisco and New York and Philadelphia and Boston. On that day over this line Dr. Bell again talked to Mr. Watson, who was now 3400 miles away. It was a day of romantic triumph for these two men and for their associates and their thousands of successors who have built up the great American telephone art.

The 11th day of February following was another day of triumph for the telephone art as a product of American institutions, for, in the presence of dignitaries of the city and state here at Philadelphia and at San Francisco, the sound of the Liberty Bell, which had not been heard since it tolled for the death of Chief Justice Marshall, was transmitted by telephone over the transcontinental line to San Francisco, where it was plainly heard by all those there assembled. Immediately after this the stirring tones of "The Star-Spangled Banner," played on the bugle at San Francisco, were sent like lightning back across the continent to salute the old bell in Philadelphia.

It had often been pointed out that the words of the tenth verse of the twenty-fifth chapter of Leviticus, added when the bell was

recast in 1753, were peculiarly applicable to the part played by the old bell in 1776. But the words were still more prophetic. The old bell had been silent for nearly eighty years and it was thought forever, but by the use of the telephone a gentle tap, which could be heard through the air only a few feet away, was enough to transmit the tones of the historic relic all the way across the continent from the Atlantic to the Pacific. Thus by the aid of the telephone art, the Liberty Bell was enabled literally to fulfil its destiny and " Proclaim liberty throughout all the land, unto all the inhabitants thereof."

The two telephone instruments of 1876 had become many millions by 1916, and the first telephone line, a hundred feet long, had grown to one of more than three thousand miles in length. This line is but part of the American telephone system of twenty-one million miles of wire, connecting more than nine million telephone stations located everywhere throughout the United States, and giving telephone service to one hundred million people. Universal telephone service throughout the length and breadth of our land, that grand objective of Theodore N. Vail, has been attained.

While Alexander Graham Bell was the first to transmit the tones of the human voice over a wire by electricity, he was also the first to transmit the tones of the human voice by the wireless telephone, for, in 1880, he spoke along a beam of light to a point a considerable distance away. While the method then used is different from that now in vogue, the medium employed for the transmission is the same—the ether, that mysterious, invisible, imponderable wave conductor which permeates all creation.

While many great advances in the wireless art were made by Marconi and many other scientists in America and elsewhere, it remained for that distinguished group of American scientists and engineers, working under my charge, to be the first to transmit the tones of the human voice in the form of intelligible speech across the Atlantic Ocean. This great event and those immediately preceding it are so fresh in the public mind that I will make but a brief reference to them here.

On April 4th, 1915, we were successful in transmitting speech without the use of wires from our radio station at Montauk Point, on Long Island, to Wilmington, Delaware.

On May 18 we talked by radio telephone from our station on

Long Island to St. Simon Island, in the Atlantic Ocean, off the coast of Georgia.

On the 27th of August, with our apparatus installed by permission of the Navy Department at the Arlington, Virginia, radio station, speech was successfully transmitted from that station to the Navy wireless station equipped with our receiving apparatus at the Isthmus of Panama.

On September 29 speech was successfully transmitted by wire from New York City to the radio station at Arlington, Virginia, and thence by wireless telephone across the continent to the radio station at Mare Island Navy Yard, California, where I heard and understood the words of Mr. Theodore N. Vail speaking to me from the telephone on his desk at New York.

On the next morning, at about one o'clock, Washington time, we established wireless telephone communication between Arlington, Virginia, and Pearl Harbor, in the Hawaiian Islands, where an engineer of our staff, together with the United States Naval officers, distinctly heard words spoken into the telephone at Arlington, Virginia. On October 22, from the Arlington tower in Virginia, we successfully transmitted speech across the Atlantic Ocean to the Eiffel Tower at Paris, where two of our engineers, in company with French military officers, heard and understood the words spoken at Arlington.

On the same day when speech was being transmitted by the apparatus at Arlington to our engineers and to the French military officers at the Eiffel Tower in Paris our telephone engineer at Pearl Harbor, Hawaii, together with an officer of the United States Navy, heard the words spoken from Arlington to Paris and recognized the voice of the speaker.

As a result of exhaustive researches too extensive to describe here, it has been ascertained that the function of the wireless telephone is not to do away with the use of wires, but rather to be employed in situations where wires are not available or practicable, such as between ship and ship, and ship and shore, and across large bodies of water. The ether is a universal conductor for wireless telephone and telegraph impulses and must be used in common by all who wish to employ those agencies of communication. In the case of the wireless telegraph the number of messages which may be sent simultaneously is much restricted. In the case of the wireless telephone, owing to the thousands of separate

wave-lengths required for the transmission of speech, the number of telephone conversations which may be carried on at the same time is still further restricted, and is so small that all who can employ wires will find it necessary to do so, leaving the ether available for those who have no other means of communication. This quality of the ether which thus restricts its use is really a characteristic of the greatest value to mankind, for it forms a universal party line, so to speak, connecting together all creation, so that anybody, anywhere, who connects with it in the proper manner, may be heard by every one else so connected. Thus a sinking ship or a human being anywhere can send forth a cry for help which may be heard and answered.

No one can tell how far away are the limits of the telephone art. I am certain that they are not to be found here upon the earth, for I firmly believe in the fulfilment of that prophetic aspiration expressed by Theodore N. Vail, at a great gathering in Washington, that some day we will build up a world telephone system, making necessary to all peoples the use of a common language or a common understanding of languages which will join all of the people of the earth into one brotherhood. I believe that the time will come when the historic bell which now rests in Independence Hall will again be sounded, and that by means of the telephone art, which to-day has received such distinguished recognition at your hands, it will proclaim liberty once more, but this time throughout the whole world, unto all the inhabitants thereof. And, when this world is ready for the message, I believe the telephone art will provide the means for transmitting to all mankind a great voice saying, " Peace on earth, good-will toward men."

PRESENTATION OF THE ELLIOTT CRESSON MEDAL TO THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY, THROUGH MR. THEODORE NEWTON VAIL, PRESIDENT.

In introducing Mr. Theodore N. Vail Dr. Keller said:

" *Mr. President:* In awarding the Franklin Medal to Dr. John J. Carty The Franklin Institute is fully aware that the marvellous achievements of this pioneer and leader in the science of telephone engineering are shared in a large measure by the corporation of which he is the chief engineer, by the men who have developed

and directed this vast business enterprise and made the Bell System what it is to-day, and by that wonderfully efficient technical staff which Doctor Carty has created and trained. In recognition of this fact, the Committee on Science and the Arts has unanimously recommended that the Elliott Cresson Medal of the Institute, the highest distinction it can confer upon a corporation, be awarded to the American Telephone and Telegraph Company for its constructive and far-seeing policy in the development of the art of telephony, in the promotion of telephone engineering, in the establishment of its telephone system in every part of the United States, and for placing all of the States of the Union in speaking communication.

To indicate the vast extent of the Bell System I may be permitted to quote a few statements from an address made by Mr. Bethell, senior vice-president of the American Telephone and Telegraph Company, at the formal opening of the transcontinental line, a little more than a year ago. The plant of the company and its associated companies then represented an investment of $850,000,000. Joining together more than 70,000 communities, it transmitted over its lines about nine billions of messages a year, or 26,000,000 a day. Exclusive of the associated companies, it employed an army of 160,000 men and women. More than twice as much has been spent upon the improvement and extension of the Bell System during the time the Panama Canal was being constructed as the entire cost of this great undertaking.

Such figures are simply staggering, and we can only marvel at the vastness of this system of communication which reaches every part of our country, and triumphantly proclaims man's conquest over space and time. With a feeling akin to awe we think of the man whose prophetic vision, unerring judgment, and matchless executive ability have guided the forces which have wrought this wondrous evolution. He comes of sturdy old Quaker stock, and some of his forbears have greatly distinguished themselves as engineers and electricians. During the early years of his career he was employed in the railway mail service, in which his pronounced ability to systematize and organize secured him rapid promotion. As general superintendent he brought the railway mail service to a state of high efficiency and did much to promote the Civil Service system. But it was with his appointment as general manager of the American Bell Telephone Company, in

1878, that he entered a field commensurate with his abilities. In spite of innumerable obstacles he succeeded in developing the invention of Alexander Graham Bell into a commercial success, and he soon realized that it had possibilities far beyond mere local service. From his first achievement in long-distance telephony—the line connecting Boston and Providence—his dominant spirit has continued to secure improvements in telephone material and construction until to-day the lines span the distance from the Atlantic to the Pacific. As president of the American Telephone and Telegraph Company he has effected the financial and technical organization of this vast corporation, and nothing could be more appropriate on this occasion than his receiving from your hands the Elliott Cresson Medal awarded to his company. Mr. President, I deem it a very great honor to present to you Mr. Theodore Newton Vail, president of the American Telephone and Telegraph Company."

The *President,* in presenting the Elliott Cresson Medal to Mr. Vail, for the American Telephone and Telegraph Company, said: "I have the honor, in the name of The Franklin Institute, as recommended by its Committee on Science and the Arts, and in recognition of the great work performed by the American Telephone and Telegraph Company in the development and perfecting of the art of speech transmission, to present to you for that company the Elliott Cresson Medal, the highest honor to a corporation in the gift of the Institute." In accepting this recognition for the American Telephone and Telegraph Company, Mr. Vail addressed the Institute as follows:

ADDRESS

BY

MR. THEODORE N. VAIL,

President American Telephone and Telegraph Company.

"*Mr. President and Members of the Institute, Ladies and Gentlemen:* On behalf of the American Telephone and Telegraph Company I accept this most complimentary tribute.

When the telephone business was first organized, the possibility, but not the magnitude, of the future was recognized. Then was adopted, after deliberation and discussion by the founders of the business, the comprehensive policy of making the telephone a useful utility, broad in its scope and universal in its application.

Theodore Roosevelt

This policy has been faithfully followed by those who have been responsible for the operations of the business.

We accept this tribute of to-day as a recognition by this great Institute and by the public that that policy was a wise one, and that it had been wisely and successfully carried out.

This tribute has another and even greater significance.

The telephone service is an individual service, rendered to individual users by the individual members of the telephone organization.

It is a service dependent upon the right thing being done at the right time, by the right person, in the right way. To the extent that all this is done the service is good; if any fail, to that extent the service is defective.

This requires on the part of every individual member: to the organization, loyalty; to their obligations, fidelity; and in the performance of their duty, conscientiousness.

This award is, therefore, a personal tribute to each individual connected with the service, to the full recognition, by them, of their obligation to the organization and to the public, and each one will so feel and appropriate it.

Gentlemen, on behalf of my company and on behalf of my associates, on behalf of every individual connected with the Bell System, please accept hearty thanks and expressions of the highest appreciation of your action."

Following Mr. Vail's address, the American Telephone and Telegraph gave an interesting demonstration of transcontinental and wireless telephony, which was repeated at intervals during the evening for the benefit of the Institute's membership and friends.

From Engine to Axle. B. W. SHILSON. (*Proceedings of the Institution of Automobile Engineers*, April, 1916.)—This paper is intended to form a link between those recently read before the Institution by Messrs. W. D. Williamson on "Engines" and G. W. Watson on "Live Axles," and deals with clutches, change speed boxes, and universal joints.

The earliest form of clutch, namely, the metal-to-metal cone clutch, has now fallen into disuse in favor of the leather cone type, and this in its turn has been almost entirely replaced by a cone lined with a bonded asbestos surface having a higher coefficient of friction and no tendency to burn. The trouble with the metal-to-metal type was, of course, its suddenness of action, and, with the leather-to-

metal type, the burning up of the leather. But experience has shown that if the angle of the cone is not less than 15 degrees the specific pressure does not exceed 7 pounds per square inch, and if the leather is well lubricated it can run with satisfaction for long periods, as shown in the case of London 'bus work. In order to keep the leather in good condition, the Mandslay Company fixes a shield to the flywheel so that the cone is always immersed in oil. In America cork inserts have been used as a friction surface, but this form of clutch has not been widely adopted on account of the uncertainty of its action.

The introduction of the multiple disk type brought troubles of its own, resulting from the dragging of the clutch and consequent gear-changing difficulties, owing to the fact that this clutch must be run in oil and the plates when pressed together drive out the air, so that they are held together by atmospheric pressure when the clutch spring is released. In the author's opinion, the most satisfactory type of clutch is a single plate held between one face of the flywheel and an axially sliding ring.

Generally speaking, the change-speed boxes in use at the present time are either of the spur or silent chain types. The small number of epicyclic gear boxes on the market are chiefly of American design. The introduction of ball bearings was found to greatly increase the noise transmitted. There is, however, a type of ball bearing in the market in which the ball cage consists of two sections of die-cast with metal, so cast as to give surface support instead of line contact, and this was found to eliminate to a large extent the noise due to spinning. A feature of ball bearing frequently overlooked by the designer is the gradual settling of the bearing into the soft aluminum housing. It is recommended that these be housed in malleable iron covers or in a separate steel sleeve. Rigidity is of the greatest importance, and this end should be kept constantly in view in designing a gear box. Square shafts have been almost entirely replaced by broached castellated shafts.

On most vehicles a high-speed brake is fitted at the back of the gear box. This can be of the internal expanding or the external contracting type, common practice favoring the latter. The best braking surface is bonded asbestos or a good quality of cast iron. Adjustment in the length of the propeller shaft to allow for the rise and fall of the axle relative to the frame is most conveniently taken up by a sliding castellated shaft. The universal joints, owing to their position on the chassis, are always liable to neglect, and great care should be taken in their lubrication. One thousand pounds per square inch has been found a satisfactory specific pin pressure. For extreme conditions of service there is no doubt that the most satisfactory joint is that in which ball bearings are mounted on the pins of the universal joint forks.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF THE INDUCTANCE OF FOUR-TERMINAL RESISTANCE STANDARDS.[1]

By Francis B. Silsbee.

[ABSTRACT.]

THE precise measurement of alternating currents frequently involves the use of standard resistances the inductance of which should be known. When the currents are large the standards used are usually of low resistance, and a very small inductance in such a standard may produce a very considerable phase angle between the voltage drop across the resistance and the current. In the range below one ohm the resistances are almost invariably of the four-terminal type and therefore require methods of measurement which are quite distinct from those applicable to higher resistances. The object of this investigation was to develop methods for comparing the phase angles of such four-terminal resistances and also to construct standards, having a very small known inductance, with which other apparatus could be compared.

If we consider a four-terminal resistance (or, more briefly, a "shunt") which carries a sinusoidal alternating current, we will find that the voltage between the potential terminals is not in general in phase with the current, but may be resolved into two components, one in phase and one in quadrature. The resistance of the shunt is defined as the ratio of the in-phase component to the current, while the reactance is the ratio of the quadrature component of voltage to the current. The angle whose tangent is ratio of reactance to resistance is the phase angle of the shunt. The inductance is, of course, equal to the reactance divided by 2π times the frequency, while the time-constant is the ratio of the inductance to the resistance. This latter quantity is very nearly constant over the range of commercial frequencies and is a measure of the amount by which a shunt departs from the ideal condition of giving a voltage exactly in phase with the current.

In some of the measurements described below it was necessary to use mutual inductances, and it was found that these did not in general satisfy the ideal condition of giving a secondary voltage in exact quadrature with the primary current, but that the voltage

* Communicated by the Director.

[1] Scientific Paper No. 281.

had a small in-phase component. By analogy with the case of the shunt we may define the " resistance " of the mutual inductance as the ratio of this in-phase component of voltage to the primary current. We will further define the " phase defect " as the angle whose tangent is the ratio of the in-phase component of voltage to the quadrature component.

The method for the comparison of the time constants of two shunts which was found most suitable may be called the Current Transformer Method. It consists essentially of measuring the apparent phase angle of a current transformer by one of the usual null methods, using in succession, as the standard resistance in the primary circuit of the transformer, the two shunts to be compared. The apparent change in the phase angle of the transformer is the difference in the phase angle of the two shunts. A group of about twenty shunts were intercompared by this method and form a basis for future comparisons. A second method involving the use of mutual inductances was tried out, and gave results in agreement with the first method, but was found to be much less convenient.

Since the comparison methods just mentioned give only the difference in time-constant of two four-terminal standards, some other measurement is needed to give the actual value of the time-constant of one four-terminal shunt in terms of known quantities. The simplest way to obtain this value is to construct a shunt of such shape that the inductance can be computed from the measured dimensions. This procedure requires that certain assumptions be made as to current distribution, etc., but a careful investigation using three different shapes of shunt showed that these assumptions were completely justified. As a check two other methods of measurement were tried, one involving the use of mutual inductances of known phase defect, and the other using two shunts constructed of identical dimensions, but of materials of different resistivities. These methods gave results in agreement with the computed values, but were less accurate and more laborious. It is believed that the time-constants of the group of shunts, ranging from 0.1 ohm to 0.00025 ohm, at the Bureau of Standards are known to an accuracy of 1 or 2×10^{-7} seconds. With a frequency of 60 cycles and an uncertainty of 2×10^{-7} seconds in the time-constant, the phase angle between the voltage and current is uncertain by about 15 seconds of arc.

Further measurements were made on other types of shunt and also on the effect of stray magnetic fields on the apparent time-constants of the shunts.

In the design of shunts for use on alternating current it appears that the liability to error can be minimized by so locating the potential leads that the inductive effects in them completely neutralize the inductance of the resistance material itself and the shunt as a whole is strictly non-inductive. The type in which the resistance material forms one or both of two concentric tubes lends itself very readily to this form of compensation.

A study of the phase defects of mutual inductances of large current capacity showed that this source of error was by no means negligible, and that it was particularly large in cases where the secondary was wound in several layers.

A more complete account of this investigation is to be published shortly in the *Bulletin of the Bureau of Standards.*

SENSITIVITY AND MAGNETIC SHIELDING TESTS OF A THOMPSON GALVANOMETER FOR USE IN RADIOMETRY.*

By W. W. Coblentz.

THE present paper gives the results of an investigation of the force exerted by various galvanometer coils when operated under standard conditions. Some of the coils were wound according to theoretical requirements, while others were wound empirically. Numerical data are given relating to coils having various resistances.

A simple coil is described, wound with a single size of wire (x 28 B. & S.), which is as efficient as a compound coil wound in three sections of graded wire upon the same mandrel.

A 9-ohm coil of graded wire is described which is very efficient and is well adapted to be used with the bismuth-silver thermopiles previously described.

A comparison is made of various astatic magnet systems and data are given showing the importance of using small mirrors, in order to increase the sensitivity.

Experiments are described on shielding the galvanometer from external magnetic disturbances. The galvanometer coils are

* Scientific Paper No. 282.

mounted in cavities cut into blocks of Swedish iron which reduce the air space and act as a magnetic shield. This elimination of convection currents greatly improves the steadiness of the needle system. Various shields are described, consisting of laminated cylinders made from transformer iron, and solid cylindrical shells cut from wrought-iron gas pipe. By imbedding the galvanometer coils in blocks of Swedish iron which are surrounded by cylindrical shells of transformer iron and of wrought iron the effect of external magnetic perturbations upon the astatic needle system is easily reduced to one two-thousandth of its original value.

Experiments on a vacuum galvanometer are described in which a sensitivity was attained which is more than ten-fold that used in the writer's previous work on stellar radiation.

THE VOLUME EFFECT IN THE SILVER VOLTAMETER.*

By E. B. Rosa and G. W. Vinal.

SOME years ago the Bureau discovered that the silver deposits in large-size voltameters were consistently heavier than the deposits in small voltameters which were used in series with them. The cause of this effect was attributed to impurities in the solution, but this explanation was not accepted by all the observers who have worked with the voltameter. Jaeger and von Steinwehr thought that because the evidence rested principally on the results with the porous-cup form of voltameter the effect was due to the porous cup. Richards, on the contrary, thought that the greater surface of the large cathodes permitted greater inclusions and therefore the deposit appeared heavier. The recent experiments of Vinal and Bovard have shown that Richards's theory is not correct, but some further experiments were necessary to answer Jaeger and von Steinwehr's contention.

The authors have analyzed all of their former observations with reference to the volume of the electrolyte, the weight of the deposit, and the purity of the solution. They have also made some further experiments with especially impure solutions and with other forms of the voltameter than the porous-cup form. All of these observations have been treated by statistical methods, and the authors show, first, that the volume effect is not confined to the porous-cup form of voltameter, but that it is common to all

* Scientific Paper No. 283.

forms of voltameter, and, second, that it is caused by impurities in the electrolyte. The authors give a theory for the mechanism of the effect, and they believe that the evidence proves conclusively that it is a valuable criterion for the purity of the silver nitrate.

CONSTANTS OF SPECTRAL RADIATION OF A UNIFORMLY HEATED INCLOSURE OR SO-CALLED BLACK BODY. II.*

By W. W. Coblentz.

A KNOWLEDGE of the exact value of the constants which enter into the mathematical equation which represents the distribution of energy in the spectrum of a black body is necessary in many physical problems, especially in extending the temperature scale higher than is possible with thermocouples.

The spectral energy curves were obtained by means of a vacuum bolometer, a mirror spectrometer, and a fluorite prism.

The present paper gives the result of a recomputation of the constants of spectral radiation of a black body, which had been published in a previous paper. This recomputation was necessitated as the result of the adoption of a new and apparently more reliable calibration curve of the fluorite prism used in the work, and as a result of the discovery of a small error which was found in the previous computations. Although these errors are small (and would have been considered negligible four years ago), they happen to be of the same sign and hence have an appreciable effect upon the final result.

The results of the present computations give a mean value of $C = 14369$, which is close to the mean value of all the published data.

The data of other investigators are summarized, and it is found that they lie close to $C = 14350$.

From a consideration of the data now available it appears that the values of the constants of spectral radiation are close to

$$C = 14350 \text{ micron deg.}$$
$$A = 2890 \text{ micron deg.}$$

and that the coefficient of total radiation is of the order of $\delta = 5.7 \times 10^{-12}$ watt cm.$^{-2}$ deg^{-4}. This indicates that the constant h of the quantum theory is of the order $h = 6.56$ to 6.57×10^{-27} erg sec.

* Scientific Paper No. 284.

DETERMINATION OF ALUMINIUM AS OXIDE.*

By William Blum.

[ABSTRACT.]

FROM observations made with a hydrogen electrode and with suitable indicators, it was found that the precipitation of aluminium hydroxide by ammonium hydroxide is complete when $[H^+] = 10^{-6.5}$ to $10^{-7.5}$, points which are approximately defined by the color changes of methyl red and rosolic acid. From a study of the various factors, the following conditions are recommended for the determination of aluminium. To the solution containing 5 gms. of ammonium chloride per 200 c.c. of solution (or an equivalent amount of hydrochloric acid) add a few drops of methyl red (0.2 per cent. alcoholic solution), and heat the solution just to boiling. Carefully add dilute ammonium hydroxide dropwise, till the color of the solution changes to a distinct yellow. Boil the solution for one or two minutes, and filter. Wash the precipitate thoroughly with hot 2 per cent. ammonium chloride or nitrate solution. Ignite in a platinum crucible, and after the carbon is all burned off, blast for five minutes, cover the crucible and place it in a desiccator till cool. Weigh (covered) as rapidly as possible. A second blasting of five minutes is desirable to facilitate rapid weighing, and consequently probably more accurate results.

THE INFLUENCE OF FREQUENCY OF ALTERNATING OR INFREQUENTLY REVERSED CURRENT ON ELECTROLYTIC CORROSION.†

By Burton McCollum and G. H. Ahlborn.

[ABSTRACT.]

THIS paper describes experimental work done to determine the coefficient of corrosion of iron and lead in soil with varying frequencies of alternating or reversed current, with 60 cycles per second as the highest frequency and a two-week period as lowest—some direct-current tests being made also as a check on the conditions. It is shown by these experiments that the corrosion of both iron and lead electrodes decreases with increasing frequency of reversal of the current, the corrosion being practically negligible

* Scientific Paper No. 286.

† Technologic Paper No. 72.

for both metals when the period of the cycle is not greater than a few minutes.

With iron electrodes a limiting frequency is reached between 15 and 60 cycles per second, beyond which no appreciable corrosion occurs. No such limit was reached in the lead tests, although it probably exists at a higher frequency than 60 cycles. It was shown that with periodically reversed currents the addition of sodium carbonate to the soil reduces the loss in the case of iron and increases it in the case of lead.

The coefficient of corrosion of lead under the soil conditions described in the report when subjected to the action of direct current was found to be only about 25 per cent. of the theoretical value; whereas the corrosion of iron was found to agree quite closely with the theoretical corrosion.

The corrosion of lead reaches practically its maximum value with a frequency of reversal lying between one day and one week; whereas the corrosion of iron does not reach a maximum value until the period of the cycle is considerably in excess of two weeks.

The most important conclusions to be drawn from the investigations is that in the the so-called neutral zone of street railway networks, where the pipes continually reverse in polarity, the damage is much less than would be expected from a consideration of the arithmetical average of the current discharge from the pipes into the earth. Where pipes are alternately positive and negative with periods not exceeding 10 or 15 minutes, the algebraic sum of the current discharged is more nearly a correct index to the total damage that will result than any other figure that can readily be obtained.

The reduction in corrosion due to periodically reversed currents appears to be due to the fact that the corrosive process is in a large degree reversible; so that the metal corroded during the half cycle when current is being discharged is in large measure redeposited during the succeeding half cycle when the current flows toward the metal. This redeposited metal may not be of much value mechanically, but it serves as an anode surface during the next succeeding half cycle, and thus protects the uncorroded metal beneath.

The extent to which the corrosive process is reversible depends upon the freedom with which the electrolyte circulates, and, particularly, on the freedom of access of such substances as oxygen

or carbon dioxide, which may result in secondary reactions giving rise to insoluble precipitates of the corroded metal. It is largely for this reason that the corrosion becomes greater with a longer period of the cycle, since the longer the period the greater will be the effect of these secondary reactions.

THE DETERMINATION OF VOLATILE THINNER IN OIL VARNISH.*

By E. W. Boughton.

[ABSTRACT.]

Two samples of varnish containing turpentine and two containing "mineral spirits" (light petroleum oil) were used in the investigation. It was found that any of the following methods gave results which were sufficiently accurate for practical purposes: (1) Steam distillation, the still being heated to 115° to 120°C. and the volatile thinner in the distillate separated from the condensed water and weighed. (2) Evaporation of the volatile thinner by heating a thin film of the varnish at 110° to 115°C. in an air-bath, the loss being assumed to be volatile thinner. (3) Brown's method:[1] A weighed portion of the varnish is diluted with a suitable volatile solvent, such as ether or chloroform, to a definite volume. An aliquot portion of this solution is flowed on a weighed glass plate, and the volatile thinner and added solvent allowed to evaporate at room temperature in air or in a current of illuminating gas. The percentage of residue subtracted from 100 per cent. is assumed to be percentage of volatile thinner. (4) Evaporation at room temperature of the volatile thinner from a film of varnish brushed out on a weighed glass plate. In all four of these methods the results for percentage of volatile thinner should be reported as the whole percentage next above the figure obtained.

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* Technologic Paper No. 76.

[1] *Proc. Amer. Soc. for Testing Mat.*, **14**, 467 (1914).

NOTES FROM THE NELA RESEARCH LABORATORY.*

THE ABSENCE OF THE PURKINJE PHENOMENON IN THE FOVEA.

By Leonard T. Troland.

CAREFUL experiments by many observers have indicated that the Purkinje phenomenon cannot be obtained if the compared visual stimuli (*e.g.*, a red and a blue light) are confined to the central rod-free area of the retina. Recently,[1] however, Hering has claimed that a very fugitive Purkinje effect can be observed during the first moments of stimulation of the fovea of a dark-adapted eye. Since the conditions under which Hering's experiments were performed do not appear to have been favorable to accurate limitation of the stimulation of the fovea, and on account of the great theoretical importance of the question, it seemed worth while to repeat the work, using an improved method.

Hering employed a field 2.08 degrees in diameter, one half of which was filled with spectral blue light and the other with red. The experiment was carried out by extinguishing the blue, then suddenly fixating the red and at the same instant turning on the blue. Three defects can be pointed out in this method: (1) The field size is too great; (2) local minuthesis ("fatigue") of the red sensation can occur before the blue stimulus becomes effective; (3) steady fixation would be very difficult to obtain at the critical instant, by this method.

In the writer's experiments a field of one degree diameter was employed. This was crossed by a central red belt, 0.34 degree wide, made up of light of wave-lengths, 654–687 $\mu\mu$. The two equal polar segments were filled with blue light of wave-lengths, 469–481 $\mu\mu$. The whole was viewed against a dark background, through an artifical pupil of 1.36 mm. diameter. In the centre of the field was placed a luminous fixation point of 0.060 degree diameter, the brightness of which was just sufficient to make it visible to the dark-adapted eye.

The subject was given five minutes' bright adaptation out-of-doors, in the late morning or early afternoon, with a clear sky and May sun. He was then immediately required to adjust the

* Communicated by the Director.

[1] *Arch. f. Ophthalmol.*, 1915, 90, 1–13.

relative intensities of the red and blue components of the test field so that either (1) the red was slightly but distinctly brighter than the blue, or (2) the two were of equal brightness. The intensity of the blue during this setting was 50 photons (see footnote to next article). The subject was now given 30 minutes' complete dark adaptation, after which he was required to fixate carefully the luminous point. Immediately upon establishment of fixation the original field was suddenly exposed to view, with the first selected relative intensities accurately maintained, but with a reduction of the absolute intensity of both components to one thirty-second of the value at which the bright-adaptation setting was made. This reduction was accomplished by means of a sector disk. Ten successive brief exposures of the field were made in this way, with a minute's rest between, and the subject was asked to judge whether, at the first instant of visibility of the field, the blue was brighter than the red (the Purkinje change).

In four separate experiments of this sort the writer found it impossible to detect the slightest trace of a Purkinje effect when fixation was accurately maintained. Peripheral fixation gave a vivid enhancement of the blue. Observations by two inexperienced subjects under the same conditions yielded conflicting results, which are to be attributed to their inability to fixate accurately. The experiment was also tried by the writer with an initial intensity of 31 photons, and 20 minutes' bright adaptation, with similarly negative results.

June 18, 1916.

THE HETEROCHROMATIC BRIGHTNESS DISCRIMINATION THRESHOLD.

By Leonard T. Troland.

THE measurements described below were made to study some of the principles underlying the "direct comparison" method of heterochromatic photometry.

Although it is always difficult to make a positive judgment that two stimuli of different color are of *equal* brightness, a ratio of intensities can easily be established for which a perfectly secure judgment of *inequality* of brightness can be delivered. Consequently, for any pair of colors it is possible to determine the *brightness discrimination threshold*, and this should be a function

of the colors, or of the difference between them. In the present investigation four standard spectral stimuli were chosen, of mean wave-lengths, 693, 575, 505, 475 $\mu\mu$, respectively, representing as nearly as possible the four psychological primaries. These were compared with each other and with nine additional colors taken at intervals of 30 $\mu\mu$ across the spectrum. The wave-length ranges of the stimuli varied from 4 to 30 $\mu\mu$, according to the position in the spectrum.

The comparison field was viewed against a dark background, and consisted of four vertically juxtaposed, rectangular areas, with a common horizontal dimension of 1.02 degrees. The upper rectangle was filled with the standard color, and the lower rectangle with the comparison color, the height of each of these areas being 0.97 degree. Between them were two bands, of height 0.34 degree each, the upper of which was filled with the comparison colors and the lower with the standard. In making the judgments, attention was directed primarily to these bands.

To determine the threshold values the "method of limits" was employed, the "standard" being subjected to variation in intensity. The relative intensities were found at which the standard was (*a*) just noticeably brighter, (*b*) just not noticeably brighter, (*c*) just noticeably darker, and (*d*) just not noticeably darker, than the comparison field. The fractional threshold values were calculated by means of the formula: $\Delta I = (I - \sqrt{IJ})/I$, where $I = \sqrt{ab}$ and $J = \sqrt{cd}$, if *a*, *b*, *c*, and *d* represent, respectively, the intensities just mentioned, enumerated. This formula is based on Weber's law.

The comparison color was held at a constant intensity which was, in all cases, approximately 25 photons,[1] a square artificial pupil 2.51 mm. on a side being used. The intensity of the comparison color was established by flicker photometry. The general conditions of observation were made, as nearly as possible, the same as those of ordinary photometric work.

The final results for two subjects, T (experienced) and L (inexperienced) are given in the following table. ΔI is the fractional threshold; v is average of the mean variations of the four intensities, *a*, *b*, *c*, *and d*; $\Delta I/S$ is expressed as fractions of these

[1] One photon is an illumination of the retina corresponding with a stimulus-surface brightness of one candle per square metre, and an effective pupillary area of one square millimetre.

intensities; $\Delta I/S$ is the threshold in terms of the homochromatic threshold as a unit; and $\Delta I/v$ is the ratio between the threshold and the average mean variation of its determining points. Each value for subject T (the writer) represents from 40 to 100 independent observations, and for subject L, 20 observations.

Standard Color	Comparison Color, μμ.												
Red, 693μμ	693	670	640	610	580	575	550	520	505	490	475	460	43
ΔI (T)	.042	.080	.092	.149	.170	.194	.185	.190	.214	.191	.195	.191	.172
(L)	.047	.076	.085	.111	.122	.135	.135	.161	.144	.139	.199	.154	.126
v (T)	.014	.024	.028	.041	.049	.052	.045	.037	.040	.044	.062	.036	.048
(L)	.016	.020	.024	.027	.030	.032	.045	.046	.026	.044	.028	.042	.045
$\Delta I/S$ (T)	1.00	1.93	2.22	3.58	4.09	4.65	4.44	4.5·	5.15	4.58	4.68	4.60	4.20
(L)	1.00	1.59	1.79	2.33	2.57	2.85	2.85	3.41	3.04	2.94	4.21	3.26	2.58
$\Delta I/v$ (T)	2.99	2.94	3.35	3.64	3.49	3.73	4.10	5.08	4.99	3.88	3.14	4.97	3.26
(L)	2.89	3.70	3.51	4.09	4.08	4.27	2.97	3.49	5.47	3.20	7.12	3.65	2.70
Yellow, 575μμ													
ΔI (T)	.150	.160	.175	.155	.097	.037	.125	.126	.185	.161	.201	.191	.169
(L)	.199	.156	.144	.104	.052	.028	.080	.125	.148	.196	.147	.156	.109
v (T)	.038	.031	.041	.043	.023	.010	.035	.026	.041	.057	.042	.032	.046
(L)	.066	.047	.039	.040	.013	.008	.029	.037	.030	.039	.060	.043	.026
$\Delta I/S$ (T)	4.07	4.57	4.75	4.20	2.64	1.00	3.40	3.43	5.00	4.37	5.45	4.97	4.54
(L)	7.22	5.67	5.23	3.76	1.91	1.00	2.91	4.55	5.38	7.12	5.36	5.66	3.90
$\Delta I/v$ (T)	3.93	5.38	4.25	3.58	4.25	3.78	3.54	4.88	4.46	2.75	4.79	6.33	3.66
(L)	2.84	3.29	2.72	2.59	3.97	3.65	2.80	3.40	4.88	5.00	2.47	3.65	4.13
Green, 505μμ													
ΔI (T)	.192	.172	.155	.153	.160	.173	.144	.122	.037	.116	.159	.147	.145
(L)	.231	.213	.206	.184	.172	.103	.117	.055	.024	.079	.072	.149	.107
v (T)	.044	.039	.041	.038	.039	.044	.029	.029	.009	.028	.032	.035	.036
(L)	.037	.026	.028	.046	.040	.033	.035	.019	.004	.024	.019	.038	.042
$\Delta I/S$ (T)	5.22	4.69	4.23	4.16	4.35	4.71	3.91	3.32	1.00	3.17	4.33	3.99	3.97
(L)	9.73	9.00	8.69	7.75	7.24	4.54	4.93	2.31	1.00	3.32	3.04	6.28	4.52
$\Delta I/v$ (T)	4.36	4.39	3.76	4.02	4.15	3.96	4.89	4.25	3.88	4.15	4.93	4.18	4.06
(L)	6.28	8.23	7.30	4.04	4.30	3.08	3.38	2.83	6.64	3.33	2.77	3.91	2.55
Blue, 475μμ													
ΔI (T)	.173	.176	.178	.131	.128	.118	.129	.129	.126	.121	.075	.174	.181
(L)	.164	.178	.183	.157	.095	.141	.103	.100	.134	.067	.062	.080	.104
v (T)	.039	.060	.053	.034	.046	.030	.036	.046	.056	.033	.013	.045	.029
(L)	.059	.030	.046	.028	.027	.030	.018	.025	.062	.010	.013	.023	.027
$\Delta I/S$ (T)	2.31	2.35	2.38	1.75	1.71	1.58	1.72	1.72	1.68	1.62	1.00	2.32	2.42
(L)	2.66	2.88	2.97	2.54	1.55	2.27	1.67	1.62	2.17	1.08	1.00	1.31	1.68
$\Delta I/v$ (T)	4.45	2.94	3.35	3.89	2.47	3.98	2.96	2.82	2.24	3.72	5.58	3.87	6.30
(L)	2.80	5.91	4.02	5.63	3.49	4.73	5.65	4.01	2.16	6.95	4.91	3.42	3.91

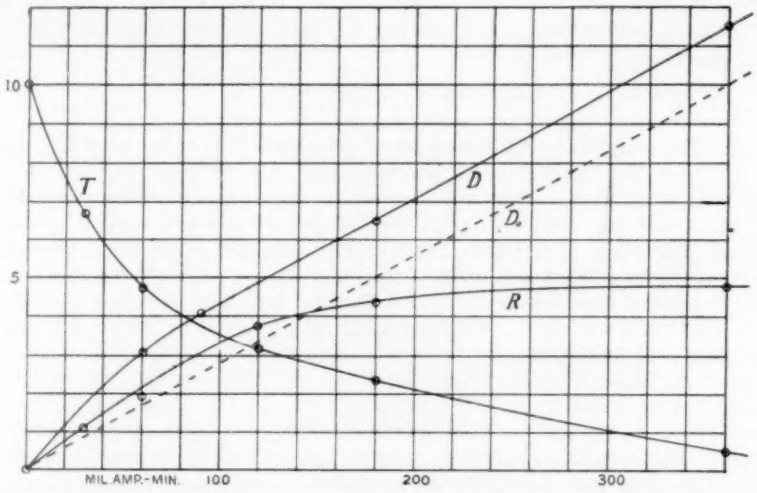
The results show that, as should be expected, the brightness discrimination threshold is a minimum for a minimum of color difference between the two compared stimuli, and that on the average it has a value four or five times its minimum, for a maximum of color difference. The data also indicate that, to the first order of approximation, degree of color similarity is proportional to the extent of participation of the same psychological primary color qualities in both of the compared fields. It is also apparent that the ratio $\Delta I/v$ is independent of the color difference. The general average value of this ratio for subject T is 4.012 (a.d. = .61), and for subject L, 4.09 (a.d. = 1.04). Hence, approximately: $\Delta I = 4\,v$.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

SOME QUANTITATIVE DATA ON CATHODE DEPOSITED METALS.†

By P. G. Nutting.

Some apparatus developed for the preparation of semi-transparent platinum mirrors, eleven inches square, giving very uniform results, a number of deposits were made to determine the variation of reflecting power, transmission, density, and mass of metal deposited with current density and time of deposit. In the larger apparatus the cathode was $279 \times 279 \times 0.05$ mm., in the smaller $120 \times 120 \times 0.1$, both of platinum with 30 per cent. iridium.



With the smaller apparatus the data shown in the figure were obtained. Abscissæ are milliampère-minutes. The curve R is reflecting power at 45 degrees incidence, T transmission, and D density ($D = \log 1/T$), measured normal to the surface. The dotted line D_0 is the density corrected for losses by reflection. Density is proportional to mass of metal, and hence to quantity

* Communicated by the Director.

† Communication No. 33 from the Research Laboratory of the Eastman Kodak Company.

of electricity. Eight points on the curves were obtained at currents of 20, 30, and 60 milliampères and running for from one to twelve minutes.

Mass per unit density and per coulomb were determined on the larger apparatus. Metal was deposited at 60 milliampère current for 12 minutes, or 0.0920 amp.-min./dm.^{2}. The deposited mirror, trimmed to 7.34 dm.^{2}, had a mean density of 0.224 and weighed 0.0125 gm. The mass per square decimetre per unit density is, therefore, 7.6 milligrammes. The silver in a photographic negative has a mass of 9 to 12 mg./dm.^{2} per unit density.

The mass of 1.71 mg./dm.^{2} was deposited by a current of 0.72 amp.-min. over 7.78 dm.^{2}, or 0.0926 amp.-min./dm.^{2}. The deposit was, therefore, 0.0185 gm./amp.-min., or 0.00031 gm./amp.-sec., compared with 0.001118 for silver. Quadrivalent platinum, deposited according to Faraday's Law, would give 0.00050 gm/amp.-sec.

ROCHESTER, N. Y., June, 1916.

Strike-a-lights. H. BRIERLEY. (*English Mechanic and World of Science,* No. 2666, April 26, 1916.)—Only 89 years ago lucifer matches were first sold at Stockton-on-Tees in boxes containing only 50 for a shilling, and some time elapsed before it was possible to buy 25 of them for a sixpence, and at the popular price of "four a penny" they were cheap only to the well-to-do. Elderly people can tell us a good deal about the use of the flint and steel and home-made non-frictional matches. Tinder had to be prepared by burning a few old rags, but some people preferred touchwood to tinder. This consisted of decayed and pulverized wood or bark, or else of certain fungi taken from trees. Tinder-boxes known as "strike-a-lights" or "strike-a-sparks" usually carried their own flint on the lid or base. The world is indebted to one John Walker, a Stockton-on-Tees chemist, who placed on the market the first match lit by friction in 1827.

Brandon, the little Suffolk town, still supplies the world with the primitive flint strike-a-lights, which not even the excellent safety match and wax vesta have not rendered obsolete. British troops during the South African campaign were supplied with Brandon flints—the best in the world—combined with steel, fuse, and lens; while Brandon gun-flints were used at the Battle of Waterloo and during the Crimean War. Spanish and Italian peasants have always been glad to secure Brandon flints, which, in one form or another, constitute part of the outfit of soldiers, travellers, and explorers in tropical lands. The modern flint, steel, and fuse combined is cheap, quite safe, and is contained in the smallest possible space.

THE FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, June 7, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 7, 1916.

MR. C. E. BONINE *in the Chair.*

The following report was presented for final action:

No. 2657.—Paint and Varnish Remover. Edward Longstreth Medal of Merit to Carleton Ellis, of Montclair, N. J., adopted.

The following report was presented for first reading:

No. 2658.—Copes Boiler Feed Regulator.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, June 14, 1916.)

RESIDENT.

PROF. LESLIE B. SEELY, head of Science Department, Germantown High School, and for mail, 5918 Pulaski Avenue, Germantown, Philadelphia, Pa.

NON-RESIDENT.

MR. G. S. LAWLER, electrical engineer, 31 Milk Street, Boston, Mass.

CHANGES OF ADDRESS.

DR. E. G. ACHESON, Care of The Acheson Corporation, Æolian Building, 35 West Forty-second Street, New York City, N. Y.
MR. ROBERT J. ANDERSON, 10839 Pasadena Avenue, N. E., Cleveland, Ohio.
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MR. C. E. SARGENT, 2020 North Delaware Street, Indianapolis, Ind.
MR. OSCAR L. SCHEHL, St. James Hotel, Woonsocket, R. I.
MR. ALBERT R. SHIPLEY, 186 Canner Street, New Haven, Conn.
LIEUT.-COL. GEORGE O. SQUIER, Signal Corps, U. S. A., care of War Department, Washington, D. C.

WILLIAM STANLEY.
1858–1916.

NECROLOGY.

WILLIAM STANLEY,

1858–1916.

Mr. William Stanley was born in Brooklyn, N. Y., November 22, 1858, the son of William Stanley, a prominent lawyer and a one-time resident of Great Barrington, Mass. The family, two years later, established a permanent residence in Englewood, N. J., where, with the exception of a few years in Berkshire and Williston Academy, Easthampton, William Stanley passed his youth and acquired his early education, largely from private tutors.

After graduation at Williston in 1876, he entered the class of 1881, Yale University.

After leaving Yale, Mr. Stanley was employed by Charles T. Chester & Co., the principal manufacturers of telegraph instruments of that time, but soon left the company to go into the nickel-plating business on his own account.

At that time Mr. Hiram Maxim (now Sir Hiram) came to Mr. Stanley's father for legal assistance in organizing the United States Electric Lighting Company, when young Stanley first became acquainted with him. Subsequently he sold his electroplating business and became one of Mr. Maxim's associates in the manufacture of electrical apparatus. His first invention was an improved system for exhausting incandescent lamps by which a high vacuum could be obtained in a shorter time than was then usual. His pumping system was patented, successfully operated, and is still used by manufacturers of incandescent lamps.

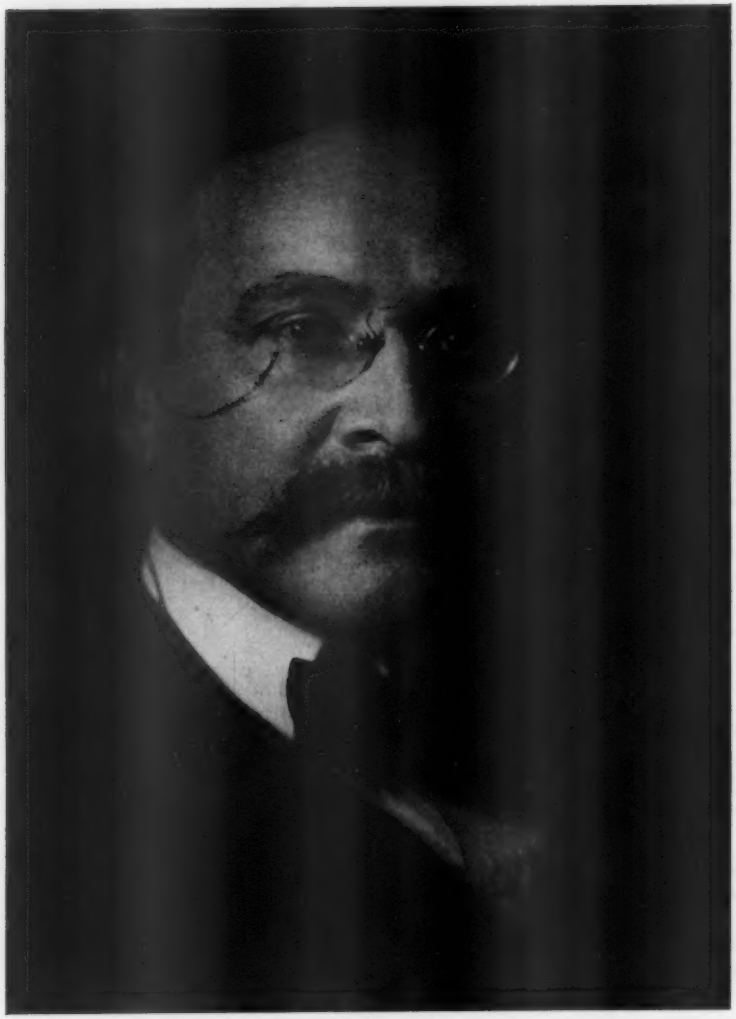
In 1880 Mr. Maxim visited the Paris Exposition, and remained abroad to perfect his rapid-fire gun. Mr. Stanley then joined, for a short time, the staff of Dr. Edward Weston. Later, in 1882, Mr. Stanley started a small laboratory of his own in Englewood, N. J.

At that time the great problem of the economic transmission of electrical energy was pressing for solution, and to it Mr. Stanley devoted his best energies.

In 1884 he became associated with Mr. George Westinghouse, an association which resulted in the Westinghouse Electric Company for the development of his inventions.

In that year Mr. Stanley built several new types of generators and motors, and installed a factory for the making of incandescent lamps, devoting most of his time to development rather than invention.

In the spring of 1885 he made and operated the first "converter," now called "transformer." During the summer and early fall of 1885, although too ill to work steadily, he gave every moment possible to the devising of a system of electrical distribution that should greatly increase the distance over which electric energy could be economically transmitted. It was during this period of illness and before he was able to return to work that Mr.



LOUIS DUNCAN.
1861–1916.

Stanley worked out the elements of the present well-known alternating-current system of transmission and distribution in general use.

In 1886 the first alternating-current plant equipped by the Westinghouse Electric Company was started at Buffalo.

Later Mr. Stanley devised several new kinds of alternating-current generators, two new kinds of alternating-current motors that have been widely used, and, with Mr. J. F. Kelly, he developed a plan for neutralizing the induction on telephone lines. In 1888 he built the first induction wattmeter, an instrument that is used for measuring the energy wherever the alternating-current service is employed.

In 1890 the Stanley Electric Manufacturing Company at Pittsfield, Mass., was organized by Mr. Stanley and his associates, Mr. J. F. Kelly and Mr. C. C. Chesney, which was later absorbed by the General Electric Company.

Mr. Stanley also patented many other devices and methods now widely used in the electrical industries. Lately he devoted much attention to thermal problems.

He was awarded the Edison Medal for his work in developing the transformer and alternating-current systems. Mr. Stanley was a member of many scientific, technical, and engineering societies; he became a member of The Franklin Institute on January 8, 1913.

DR. LOUIS DUNCAN,

1861—1916.

Dr. Louis Duncan was born in Washington, D. C., March 25, 1861, and died February 13, 1916, at Pelham Manor, New York.

He was educated in country schools in Maryland, Virginia, and Tennessee until his entrance into the East Tennessee University. After one year's attendance there he was appointed to the United States Naval Academy from Kentucky, graduating twenty-third in his class in 1880. After two years' cruise in the Pacific Station he took his examination for Ensign, standing first in his class. He was then detailed to Johns Hopkins University to assist in the work of determining the absolute unit of electrical resistance for the United States Government, receiving the degree of Ph.D. for this work in 1885 from the University.

He resigned from the Navy in 1886 to take the Chair of Electricity at Johns Hopkins University, where he continued until 1899. During these years he was continuously occupied in engineering work. He had charge of the construction of a number of electric roads in Baltimore; was consulting engineer for practically all the electric roads in Washington, and was engineer for the Baltimore and Ohio Company and installed the 100-ton electric locomotives which haul trains through the Baltimore Tunnel. He resigned from Johns Hopkins University in 1899 and became chief engineer and had charge of construction of the Third Avenue System in New York. In 1902 he was called to inaugurate the Electrical Engineering Course at the Massachusetts Institute of Technology, remaining as head of the Electrical Engineering Department until his resignation in 1904. As a member of the firm of Duncan & Hutchinson he was consulting engineer for the New York Rapid Transit Commission on

the Subway. He was chief engineer for the Keystone Company of Philadelphia and of the independent telephone systems in Baltimore and Pittsburgh. He was also consulting engineer for the Cincinnati Traction Company, the Indianapolis Traction Company, and a large number of other electric railroad companies in the middle West. He was an expert in many important patent litigations. At the time of his death he was president of Duncan, Young & Company, New York. He was chairman of the Board of Judges at the International Electrical Exhibition in 1884; on the Board of Judges of the Atlanta Exhibition, and of the World's Fair at Chicago, and chairman of the Electric Railroad Section of the St. Louis Exhibition.

Dr. Duncan contributed the articles on "Electric Traction" in the 10th and 11th Editions of the Encyclopædia Britannica and was the author of many scientific papers.

He was lieutenant-commander in the Maryland Naval Reserve, and at the outbreak of the Spanish-American War was appointed major of the First Battalion of the First Regiment of Volunteer Engineers.

Dr. Duncan was a Fellow of the American Institute of Electrical Engineers and twice its president, 1895-'87; a member of the American Electrochemical Society, Société Mathematique de France, Société de Physique, and of many other learned and technical societies in America and Europe. He was elected an honorary member of The Franklin Institute on November 11, 1885, and became an associate editor of the JOURNAL in 1912.

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The Strength of Clamped Splices in Concrete Reinforcement Bars. E. L. LASIER. (*Proceedings of the American Society for Testing Materials,* June 27 to 30, 1916.)—Concrete reinforcement bars are received in lengths varying up to about 60 feet. The length most commonly selected, however, is in the neighborhood of 30 feet; hence it is frequently necessary in practice to lap one bar over another. It is also desirable upon more or less frequent occasions to secure a splice capable of withstanding a greater tensile stress than that which a plain lap splice can resist. In such cases, U-bolt clamps, such as are ordinarily used in fastening wire cables together, have been successfully employed, one at each end of the overlapping bars. The meagreness of available data on the strength of such splices prompted the tests, the results of which are here recorded.

U-bolt clamped splices of both 17- and 21-inch lengths of splice were tested to determine the load at first slip, and the maximum load the splice would resist. Three different classes of splices were thus tested: Lap splices not embedded in concrete; butt splices not embedded in concrete; lap splices embedded in concrete. The reinforcement steel in all cases consisted of 1-inch square cold-twisted bars.

The loads necessary to produce first slip had a range from 7000 to 50,000 pounds. The maximum load which the splices withstood varied from 23,000 to 69,000 pounds. The ratios of load at first slip to yield point of bar for clamped splices not embedded in concrete varied from 12 to 21 per cent., and for splices embedded in concrete from 53 to 83 per cent. Ratios of maximum load to tensile strength of bar ranged from 31 to 61 per cent. for unembedded splices, and from 79 to 95 per cent. for embedded splices.

It was found: (1) That lap splices are stronger than butt splices. (2) That splices in which the two overlapping bars are of opposite twist apparently are stronger than splices in which the bars are of like twist. (3) That the lengths of lap, as to the two lengths tested, did not affect the strength of the splice. (4) That embedding the splices in concrete increases their strength materially. (5) That clamped lap splices embedded in large masses of concrete undoubtedly can safely withstand a unit load equal to the unit stress of the steel reinforcement.

CURRENT TOPICS.

Refinements in Illumination. ANON. (*Electrical Review*, vol. 68, No. 23, June 3, 1916.)—Nothing better illustrates the flexibility of electric lighting than special applications in which the central-station engineer or the fixture designer solves a problem on a plane above ordinary practice. It is no exaggeration to say that the industry has only begun to appreciate its opportunities in this field. Some of these problems may be stated to advantage. There is a demand now, limited, to be sure, but considerable when the possibilities are studied, in the way of providing efficient illumination for the pulpit in chapels serving the deaf, so that lip-reading can be done by the congregation, which cannot get the preacher's meaning by the ordinary methods of communication. Temporary installations have been made which are much better than many of those where no special study has been given to the problem, but in the provision of suitable apparatus to gain the above result without disturbing glare the illuminating engineer can find an interesting and promising test. The need of an installation of this kind was expressed in a recent article in a church periodical by a clergyman experienced in ministering to the deaf, and without question the refinements of modern illumination are equal to the problem.

There is a possibility that the not distant future may witness a demand for a new type of art-museum illumination: that is, for an installation in which artificial light will completely supersede daylight. It is a question whether efforts to maintain a double standard of lighting in such places are worth while, in view of the difficulties of securing equally good results with both. It is also worth investigating whether the use of electric lighting with suitable reflection and diffusion may not be better adapted to the maintenance of life in delicate exhibits, like certain entomological specimens, animal skins, and even tapestries to which a prolonged daylight exposure may be detrimental. Certainly the day has come when the use of museums at night is a consideration of some importance in the large centres, and there is no doubt that conference between the illuminating engineer and the curator might work out plans of lasting benefit to both. A museum load on the daylight schedule makes pretty satisfactory long-hour business from the central-station standpoint.

Other opportunities lie ahead of the lighting expert in the fields of hospital ward and private-room illumination, in the more artistic and better-diffused lighting of hallways in old apartment houses, in the concentration of luminous flux on street-corner signs, and in the adoption of the principles of short-range flood lighting to the requirements of fine residences. The variety of such problems in matters of detail is amazing, and every time one of these is well solved the whole art of illumination is advanced, with a correspondingly im-

proved outlook for the commercial side of such work, even down to the greater sale of supplies and the increase of central-station outputs.

Coal Mine Illumination. R. E. SIMPSON. (*Transactions of the Illuminating Engineering Society*, vol. xi, No. 2, March 20, 1916.)—Coal mining ranks as one of the most dangerous industries in which man is engaged, and this is true not only because of the high accident rate, but also because of the serious nature of many of the accidents. One of the factors that contribute to this high accident rate is the inadequacy of the illumination in coal mines. There are very few industries, if any, in which the illumination is so wretched and at the same time where good illumination is so necessary for the safety of the men. But the problem of providing adequate illumination in a coal mine is not easily solved. The use of illuminating gas is out of the question: first, because the open flame will ignite methane and cause explosions; second, because illuminating gas is itself so explosive that no mine owner would permit the introduction of such a hazardous element in the mine; and, lastly, because the cost of piping would be prohibitive. The use of electricity is likewise impracticable, because the cost of wiring the miles and miles of entries and working places precludes it, except at important switching points. There remains, then, only some form of portable light available for general coal mine lighting.

In the early days of coal mining, and even to-day in some instances, candles were used at the working places and along the haulage roads. Under average working conditions, they rarely gave a full candle-power; a fair average would be 0.8 candle-power. In addition to their inadequate power, like all open-flame light sources, they are unsafe in gaseous mines. The open-flame oil lamp, giving from 1 to 4 candle-power, consisting of a metal oil container and a spout for a cotton wick, was next introduced. With crude petroleum, which is generally used, they give a deep orange color, smoky flame, and their flickering light is very trying on the eyes. These open-flame lights exposed the mines to the danger of explosion of methane, however, and this condition made necessary the use of a light that would not ignite the gas. The safety lamp, which is essentially a cylinder of gauze placed about the flame, not only prevents the flame from igniting any gas that may be present, but is also used to indicate the percentage of gas present by the variation in size of the cap at the tip of the flame. Considered for illuminating qualities only, these lamps leave much to be desired. They seldom give more than 1 candle-power, and, under working conditions, from 0.2 to 0.5 candle-power with poor distribution. The acetylene lamp, known among miners as the "carbide lamp," is by far the best open-flame lamp in use in coal mines to-day. With a reflection equipment it gives a light of 4 to 6 candle-power, smoke-free, and whiter than that of the other lamps mentioned.

The storage-battery electric lamp, commonly known as the electric cap lamp, has many advantages over the other types. It emits neither smoke nor odor, and when equipped with a proper reflector a lamp of 1 candle-power will project a beam of light five to ten times as great through an angle of 130 degrees. As its advantages become better known, it may be expected to replace the other types now in use.

The Marseilles-Rhone Canal. ANON. (*The Times* (London) *Engineering Supplement*, No. 499, May 26, 1916.)—The piercing of the Rove tunnel on the Marseilles-Rhone Canal was formally celebrated at the beginning of this month, and the event marks an important stage in an enterprise which has been under construction for a considerable time and has been contemplated for still longer.

The idea of a canal which should enable barges to reach the Rhone from Marseilles without traversing the Mediterranean and the mouth of the river is nearly a century old, but, though various plans have been put forward from time to time, it was not till 1903 that the project was sanctioned as a part of the large scheme for the development of inland navigation in France. From Marseilles the canal runs along the coast as far as La Lave, separated from the sea by a dike, and then, turning northward, passes under the hills in a tunnel which has now been pierced. On emerging from the tunnel it passes through a cutting over a mile in length and nearly 100 feet deep at the deepest point, and then, skirting the southern side of the Etang de Berre, passes through Martigues to Port de Bouc, on the Gulf of Fos, whence it utilizes an existing canal to Arles on the Rhone. Its total length is about 48 miles, and the cost is estimated as over three and one-half millions sterling.

The tunnel, which accounts for more than two-thirds of this sum, was begun in 1910. It is about four and one-half miles long and 72 feet wide, and has a towing path six and one-half feet wide at each side, leaving 59 feet for the waterway proper. The depth of the water through the tunnel between Marseilles and Etang de Berre is nearly 10 feet, and 8 feet in other sections. The locks are to have an available length of nearly 525 feet and an entrance width of 52½ feet, or double the beam of the 600-ton Rhone barges. Although the work is hampered by the war, it is hoped to have the canal ready for traffic in three years.

Ernolith: A New Celluloid Substitute. ANON. (*Scientific American*, vol. cxiv, No. 24, June 10, 1916.)—It is only in recent years, and largely owing to the researches of the Berlin Institute of Fermentive Industries, that the very remarkable properties of yeast, aside from its levitating power, have been realized. Not only can valuable extracts be obtained from it, useful as flavoring matter and for tonic and medicinal qualities, but it contains a relatively large percentage of protein, or albuminious matter. Finally, the mass of

cellulose, its remaining constituent, composed of uncommonly tiny and delicate cells, is capable of various reactions with other substances. This latter property has been taken advantage of for the formation of plastic masses by combination with aldehydes. When these masses are subjected to heat under pressure a hard solid is obtained, known as ernolith, which makes an excellent substitute for celluloid, ebonite, galalith, bakelite, resinite, etc.

Two research chemists, H. B. Blücher and E. Krause, whose work is reported in the *Chemiker Zeitung*, have been able to vary the degree of hardness and elasticity of this product within certain limits. The color, which is originally black, can also be varied by the incorporation of mineral or vegetable dyes, so that shades of yellow, gray, brown, red, green, and blue can be obtained, as well as marbled or veined effects. To the fundamental components of ernolith, yeast, and aldehyde (particularly formaldehyde), other constituents may be added which cause a modification of the chemical and mechanical properties.

The process of manufacture consists of two phases: first, the union of the yeast and the aldehyde (with various "fillers" and subsidiary reactions). The mass thus obtained is dried and ground, and in this form is indefinitely durable. This powder is known as "half fabricate" or "raw ernolith." The next step is its compression in heated hydraulic presses. The articles thus obtained are said to reproduce on their surface the most delicate details of form, such as, for instance, those of relief maps, etc. Aside from this capacity for being directly moulded, ernolith is capable of being sawed, filed, bored, turned, engraved, ground, polished, and otherwise mechanically acted upon. It has an exceedingly close, dense structure and a conchoidal fracture. As remarked, the process may be so varied as to make the product very hard and brittle, or softer and more elastic, as may be required. It possesses a very decided advantage over celluloid in being almost entirely uninflammable, being very difficult to char. Another valuable property lies in the economy of production, since the raw powder may be precisely measured, thus avoiding trimming and scrap. Its specific gravity when pure (*i.e.*, without fillers) is 1.33 to 1.35. Ernolith also has the quality of adhering very tightly to metal threads and tissues pressed into it. This makes it highly adapted to the manufacture of articles with a metal surface or core. As primary material, it is possible to employ not only the ordinary waste yeast of breweries, but also the "air-made" yeast of the Delbrück process.

Five Years' Progress in the Industrial Fellowship System. (*University of Pittsburgh*, March 1, 1916.)—In March, 1911, the late Robert Kennedy Duncan inaugurated the Industrial Fellowship System at the University of Pittsburgh, in the Department of Industrial Research, now known as the Mellon Institute of Industrial Research of the University of Pittsburgh. The Industrial Fellowship

System represents a sane, practical plan of coöperation between industry and learning for increasing the efficiency of American industry.

The first Fellowship was founded through a grant from a baking company, which desired to improve its product. The sum of money given by this concern was used, as has been all the money which has been contributed to Fellowships, with the exception of small sums for the purchase of apparatus and chemicals, to secure the services of a man who had shown a gift for research, to devote all his time to certain problems connected with the baking industry.

During the five years which have elapsed since the establishment of the first Fellowship, 47 distinct concerns have endowed some 105 one-year Fellowships. They did this in the belief that the Mellon Institute was in position to mobilize and to concentrate all of the advantages and opportunities known to science for the solution of their particular problems. The new building of the Institute is the most complete and modern industrial experiment station in the country, and, together with the permanent organization and connection of the Institute, gives very exceptional advantages for the successful prosecution of industrial research work.

The total amount of money contributed to the Institute for the five years ending March 1, 1916, was $360,400. In addition to this sum, over $300,000 was expended by these concerns in the construction of experimental plants and $21,300 was awarded in bonuses to Fellows for the successful completion of problems.

During the five years the Institute itself expended about $175,000 in taking care of the overhead expenses in connection with the Fellowships. Besides this amount, the new building and the permanent equipment of the Institute represent an investment of between $300,000 and $350,000.

That the results obtained under the Industrial Fellowship System of the Mellon Institute have justified the expenditure of these sums of money, both on the part of industrial concerns and the Institute itself, has been shown by the fact that during the first four years—March, 1911, to March, 1915—seven out of each ten problems assigned to the Institute for study were solved to the satisfaction of the donors. A large percentage of the Fellowships were renewed, showing the confidence which industrialists have in the Institute. Twenty-five patents have been granted to the holders of Fellowships, and there are as many more pending. Above all, some twenty new processes developed in the Institute are now in actual operation on commercial scales.

At the close of the first five years of the Industrial Fellowship System at the Mellon Institute, it can be said that the plan of coöperation between science and industry which it represents has demonstrated its genuine value to American industry, and that the Institute looks forward with hope and confidence to its future development.

The Ignition of Gases by Impulsive Electrical Discharge. W. M. THORNTON. (*Proceedings of the Royal Society*, Series A, vol. 92, No. A641, May 6, 1916.)—The ignition of gases by impulsive discharge is considered first as a function of sparking distance. It is shown that the shorter the distance the greater the spark, so that the volumes of the least igniting spark are, in a typical case, the same for all spark lengths. Ignition may occur with intense momentary brush discharge, generally with the true disruptive sparks. The products of combustion are found to be ionized and to carry a positive charge.

The gases examined were mixtures in air of hydrogen, methane, propane, and pentane; ethylene and acetylene; carbon monoxide and cyanogen; coal gas and a mixture of equal volumes of hydrogen and methane. Hydrogen, propane, pentane, and carbon monoxide rise gradually in difficulty as the percentage of oxygen is reduced; methane is ignited by the same spark, whatever the percentage of gas may be; acetylene and cyanogen have the stepped atomic type of ignition; ethylene is more inflammable in rich mixtures. Hydrogen and methane in equal volumes are ignited as methane in type, hydrogen in magnitude.

The limits of inflammability of the paraffins are shown to be reached: the upper limit when there is twice the volume of combustible gas to that in the mixture for perfect combustion, the lower limit when the volume of oxygen is twice that for perfect combustion, less 1 atom to the molecule. The ignition of coal gas is through methane. Four types of electric ignition are given, covering all from the most rapid to the slowest rate of discharge from the poles. The work gives direct evidence that ignition begins by ionization of the oxygen in the mixture.

The Absorption of Gas by Quartz Vacuum Tubes. R. S. WILLOWS and H. T. GEORGE. (*Proceedings of the Physical Society of London*, vol. xxviii, part iii, April 15, 1916.)—It is a common experience to those who work with vacuum tubes, once the electrodes are freed from gas, the continued passage of the discharge lowers the pressure, and the tube eventually evacuates itself to such an extent that further discharge is impossible. This gives rise to much trouble in X-ray technic, and, as gas pressure regulators have to be added, complicates the construction of the tubes. These disadvantages have only recently been surmounted in the well-known but costly Coolidge tube. It is, therefore, a matter of great practical importance to gain some knowledge of this process of self-evacuation.

The experiments are a continuation of those of Willows and Hill on the absorption of gas which is brought about by the electrical discharges. A new quartz bulb does not absorb air, but if it be fed with repeated doses of hydrogen—which are absorbed when an electrodeless discharge is passed—it then becomes very active. If dis-

charges in hydrogen are alternated with those in air the bulb can be made to absorb large quantities of either gas, and the activity with each gradually increases. The authors reject the theory of surface absorption and, in their own experiments at least, also Swinton's theory that the gas is shot into the walls and held there. It is supposed that chemical actions occur with air, and oxidation products are formed; these are reduced by hydrogen. The process is compared with the formation of the plates in a Planté cell. Attempts to produce the same effects by chemical treatment are partially successful, particularly in fatiguing the bulb so that no further absorption takes place. The conditions under which the primary and secondary hydrogen spectra appear are also described.

Effects of Atmospheres Deficient in Oxygen on Small Animals and on Men. G. A. BURELL and G. G. OBERFELL. (*Bureau of Mines,* Technical Paper 122, November, 1915.)—In studies of the composition of mine atmospheres as related to the health and safety of miners, the writers of this paper have observed that small animals, such as mice and canaries, are not quickly sensitive to atmospheres deficient in oxygen, and hence may not indicate to exploring parties in mines that the oxygen content of an atmosphere is dangerously low. For this reason a series of tests was conducted to determine the sensitiveness of canaries and mice to such atmospheres; also, some information was obtained as to the effects of such atmospheres on men.

Deprivation of oxygen was found to cause collapse in men about the same time as it does in mice and canaries. The animals may collapse in atmospheres of different composition, and presumably the same is true of men. The fact is evident that birds and mice cannot be used safely as indicators of atmospheres low in oxygen by exploring parties in mines. Canaries are slightly more susceptible to "oxygen want" than are mice, and are chiefly valuable for indicating the presence of carbon monoxide, to which they are much more susceptible than man. In mixtures of air and nitrogen containing about 7.6 to 7.8 per cent. oxygen, canaries show pronounced distress. When the oxygen content is about 7 per cent. mice show considerable distress, and a man is in grave danger of dying; hence canaries and mice should not be used by exploring parties in mines to show when men unequipped with breathing helmets should retreat, because the atmosphere is low in oxygen. Mice and canaries, especially the latter, are chiefly of value for indicating to exploring parties the presence of dangerous proportions of carbon monoxide. In an atmosphere in which oil-fed lamps will not burn, an exploring party should not depend upon canaries for further guidance, but should use breathing apparatus in advancing into the atmosphere.

The Extraction of Gasoline from Natural Gas by Absorption Methods. G. A. BURELL, P. M. BIDDISON, and G. G. OBERFELL. (*Metallurgical and Chemical Engineering*, vol. xiv, No. 11, June 1, 1916.)—The absorption method of extracting gasoline from natural gas consists in bringing natural gas in contact with an oil heavier than gasoline, *i.e.*, a petroleum distillate of about 34 deg. Baumé, letting the absorbent absorb the gasoline from the natural gas, and then separating the gasoline from the oil by distillation. The oil is simply used as a carrier of the gasoline from the absorption tank to the still. It is used over and over again.

This method is different from the extraction of gasoline from casing-head natural gases by the compression and condensation method. By the latter method, natural gases that are comparatively rich in gasoline vapor are treated, *i.e.*, those carrying upwards of ¾ gallon of gasoline per 1000 cubic feet of natural gas. So-called "dry" natural gas cannot be treated by this method. By "dry" natural gases are meant those used in cities, towns, and factories for heating, lighting, and other purposes. The quantity consumed of this kind of natural gas amounted, in 1914, to 591,000,000,000 cubic feet. Most of this natural gas carries gasoline to the extent of one to two pints per 1000 cubic feet of gas. Probably 75,000,000 gallons of gasoline per year can be obtained by treating much of this natural gas at the present time. In the case of two natural gases that the authors of this paper experimented with, the heating value was lowered only 3.8 per cent. in one case and 2.2 per cent. in another case by the extraction of the gasoline. Besides the obtaining of valuable fuel, gasoline, a further advantage of the process lies in the resultant protection of pipe lines against the deteriorating effect of gasoline on coupling rubbers.

The absorption process of extracting gasoline from natural gas assumed industrial importance as the demand for gasoline increased. The scheme is practically identical with the process of extracting benzole and toluol (light oil) from coke-oven gases, a process used for years in Germany and to a very large extent during the years 1915 and 1916 in the United States. A difference lies in the fact that coke-oven gases are treated at about atmospheric pressure, while natural gas is treated at pressures as high as 200 to 300 pounds per square inch. This is an economic necessity, because natural gas is transported at high pressures and it is not desirable to disturb the system. To the best of the authors' knowledge, the first large-scale installation for extracting gasoline from natural gas by the absorption process was placed in Hastings, W. Va., by the Hope Natural Gas Company, of Pittsburgh, Pa.

All natural gases, except those that contain methane only as the combustible gas, contain gasoline vapor. However, in some cases, the amount contained may be very small. This is sometimes due to the fact that gas wells are under very high pressures, and this high pressure keeps the gasoline back in the well. But even those high-

pressure wells represent potential sources of gasoline supply, in that natural gas will carry commercial quantities of gasoline vapor as the pressure declines. Natural gas from two different fields that the authors tested contained gasoline to the extent of one pint per 1000 cubic feet in one case and 1.5 pints in another case. About 50,000,000 cubic feet of natural gas per day were available for treatment.

Oils which the authors experimented with to act as absorbents for the gasoline were about 35° Baumé specific gravity and started to boil at about 400° to 462° They were petroleum distillates. It is necessary that their boiling-point be much higher than the boiling-point of gasoline to make the extraction of the latter by distillation easy. Some tests were made in which the natural gas was simply passed into a naphtha of about 55 ° Baumé. Yields varying between 300 and 500 per cent. greater than that by the oil absorption and distillation process were so obtained.

Permanence of Writing-Ink. D. B. DOTT. (*Journal of the Society of Chemical Industry*, vol. xxxv, No. 9, May 15, 1916.)—Attention was first called to the bleaching effect of air and light on writing-ink, as used in modern times, by the fact that signatures on certain certificates had become illegible through the fading of the ink. As it was impracticable to test a sample of ink by exposure of writing for a period of years, it was considered that a limited application of hydrogen peroxide would be the nearest chemical equivalent to the bleaching effect of the atmosphere. Writing done by different inks was exposed to light, the paper being occasionally moistened with a 3 per cent. solution of hydrogen peroxide, the result being that the handwriting gradually became invisible, in some cases more quickly than in others. Taking ferric tannate, indigo, and aniline-blue as the principal substances used in making writing-ink, it was found that all of them are rapidly decolorized by warming with hydrogen peroxide solution. With solutions of these substances in test-tubes at the ordinary temperature the same change was slowly produced. The violet ink used for typewriters was less readily acted on, but was quickly bleached by sulphurous acid. If an ink could be produced possessing the desirable properties of perfect fluidity and being non-depositing, and at the same time incapable of being decolorized by oxidizing or reducing agents, there would be good reason to believe that the writing done by such an ink would be practically permanent. In the meantime, when writing is of an important nature and is desired to endure, some form of carbon ink appears to be the only trustworthy preparation.

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